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A Discourse Analysis of Student-to-Student Conversations in a Secondary School Physical Science Laboratory Setting

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A Discourse Analysis of Student-to-Student Conversations in a Secondary School Physical Science Laboratory Setting

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ABSTRACT

This qualitative grounded theory study applies Discourse Analysis (DA) to focus on the student-to-student (SS) "productive conversation" occurring within groups engaged in several activities in a physical science laboratory with a goal to identify aspects and patterns of such conversation. In this study, Student-to-Student Productive Talk (SSPT) stated in relation to the accepted definitions of classroom productive talk. SSPT is *on-topic* discussion between students that meet the requirements of productive conversation such as visible thinking and argumentation. The form of analysis applied in this study was derived from Classroom Discourse Analysis by Cazden (2001), Gee (2014a; 2014b), and Rymes (2016).

Conversations showed specific patterns and qualities of SSPT. All previously identified patterns of SS talk were seen including *I-R-E, open-chain,* and *closed-chain* but there were interesting ways in which these patterns appeared in the laboratory settings examined. The four labs examined involved students in different ways including 1) building components to analyze, 2) testing chemicals for their identity (by flame and by precipitate), and 3) engaging in a computer simulation. The analysis of the groups' data showed results of a slightly more dominant pattern of interaction which was the *open-chain* pattern, which excludes the final evaluative statement as found in the *closed-chain* and *I-R-E* patterns. The secondary interaction was *closed-chain*, but there were minimal triadic (*I-R-E*) patterns within the student discussions. When considering the type of lab activity and the accompanying demands made on students, the conversation patterns provided clues as to how to encourage SSPT in lab activities. The issues of authority and identity as seen through *identity work* proved to be an interesting component of the patterns and further research in this regard is suggested.

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DEDICATION

To the Loves of my Life: *My partner in Life and Crime*, Sean; *My Editor in Chief and Mom*, Suzette; and *My Two Biggest Cheerleaders*, MawMaw and Papa

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CHAPTER I: INTRODUCTION

The purpose of this qualitative grounded theory study is to examine student-to-student dialogues occurring in a physical science laboratory setting to understand better what types of dialogue the students use while engaged in laboratory activities where student-to-student discourse is encouraged. Little "d" discourse is defined as language-in-context, or language-in-use. As will be illustrated in the literature review, researchers have investigated topics related to classroom discourse, particularly in various classroom settings and subjects and focused on teacher-student or teacher-class interactions, and when focused on student-student interactions the studies were only for certain populations (i.e., ESL) of students. What all students are talking about and how they talk when they are self-guided was largely unanswered prior to this study.

As educators continue to look for ways to improve student learning , the use of student-led activities and student-guided instruction is gaining in popularity. Such approaches have been utilized and studied in classrooms across subjects (Bernot & Metzler, 2014; Chan & Bauer, 2015; Preszler, 2009; Snyder et al., 2016; Volet et al., 2017). However, the specific use of student-to-student dialogue has been studied less than other forms of student-led activities, particularly in science classrooms.

One main teaching style to encourage student-led activity and conversations is known as Dialogic Teaching. Conversation and dialogue can be used interchangeably in this study, though the Oxford English dictionary distinguishes them by stating conversation is somewhat informal exchange of ideas and dialogue usually is seeking exploration or resolution of a particular subject or problem. This style of teaching is more than just classroom talk, it is a discrete element of pedagogy. Talk is variously defined, and conversation or dialogue can be included as "talk", but talk as used in most of the literature, and in this study, is defined as primarily one person speaking while all others are listening, whereas dialogue and conversation are representative of two or more voices in concert with one another.

However, it is also a philosophy, a stance, and an outlook which together push for the full agency of all classroom actors, teacher, and students alike (Abd Elkader, 2014; Alexander, 2008; Bakhtin & Holquist, 1981; Bignell, n.d.; Jay et al., 2017; D. Kuhn & Crowell, 2011; Kumpulainen & Lipponen, 2010). It is in a dialogic classroom that dialogue is encouraged, whether it is between teacher and students, or students and students. Dialogic teaching is supported by the work of Vygotsky and Bakhtin who agreed that dialogue was and is key to appropriation of concepts (Bakhtin, 1981; Morris, 1994; Vygotsky, 1934, 1962, 1978). Many authors have offered definitions of Dialogic Teaching, but the most comprehensive is that of Robin Alexander who has worked on clarifying and defining it since the early 2000's. Alexander (2020) states that Dialogic Teaching

> harnesses the power of talk to engage interest, stimulate thinking, advance understanding, expand ideas, and build and evaluate arguments, empowering students for lifelong learning and democratic engagement. Being collaborative and supportive, it confers social and emotional benefits too. (p.1)

While there have been many studies of Dialogic Teaching, there is a need to study student-student dialogue more specifically, particularly in situations of extended Student-student (SS) dialogue like that which occurs during lab activities and paired or grouped learning where most of the talk is directed solely by the students.

Student-to-student dialogue needs to be analyzed more carefully because dialogue has been identified as a critical factor in building knowledge (Clark & Lott, 2017; Osborne et al., 2013; Schuitema et al., 2011). If teachers do not know what is happening during SS dialogue, they will not be able to harness the possible learning opportunities in SS discussion. Without knowing how students talk with each other, the teaching lore of any time students are talking to each other they are off task will persist and continue to challenge teachers who know the value of SS dialogue but have to convince their colleagues and administration of otherwise. Wilcox and colleagues (2015) discuss this myth and call it the chaotic myth. Alexander (2020) refers to the recent “idle chatter” comment made by the British Education Minister confirming the idea that student talk is naturally always idle and off topic. If anyone supports this theory, then is necessary to demonstrate that students do have productive conversation and talk when given the opportunity.

Student-to-student dialogue is challenging to study, which may explain why it has been investigated less than other types of classroom conversation (teacher-student). There are specific scenarios in a classroom that are easy to identify and record with teacher to student talk. In comparison, it is harder to guarantee SS dialogue other than a few seconds to a few minutes of a turn and talk or a think-pair-share. It is difficult to capture all the conversations, and the students may not talk as freely and as openly with the knowledge of being recorded. Even when there are long periods of student-to-student talk, students may feel uncomfortable being recorded which leads to the first couple of minutes to sound very scripted, and the talk may be directed to the listener rather than the other student. In some cases, this may never resolve itself into more natural conversations, but recording for longer periods such as during lab activities and using small inobtrusive equipment may be useful in getting the students to be more natural.

Even when a teacher sees value in SS dialogue, it can be challenging to introduce it in the classroom. For instance, one key issue is that teachers must reserve time in the classroom for student conversation and determine what counts as “productive” conversation so they can support their use of SS dialogue. Overcoming the off-task myth will continue to be a challenge for those teachers whose colleagues and administrators hold this concern.

Students normally may already be having conversations that lead to learning about the topics encountered in class. However, those conversations have not been systematically studied in the science classroom. There are many opportunities for SS conversations in science. One place where students must communicate with each other directly is in laboratory activities. In such a setting, small groups of students work together to perform a task that ostensibly will help them gain an understanding of the concept at hand.

Laboratory work can be exploratory, informational, conformational, or some combination of these and the context and demands of a given activity will likely impact the nature of student conversations. Students must discuss things like procedure, techniques, results, and conclusions to gain the needed knowledge of the activity. Hofstein (2015) points out that historically the research on lab work only shows improvement to manipulating skills but it did not consider conversation, reflection and overall student interaction. In more recent work there has been evidence of more meaningful learning in the laboratory due to the ample opportunities for interaction and reflection. He was not necessarily discussing specific student-student conversation but since most lab work is done in small groups; it would provide opportunities for those conversations to help achieve the more meaningful learning.

There have been many analyses of classroom talk in various subjects (e.g., Brooks & Dixon, 2013; Resnick et al., 2015; Schuitema et al., 2011; Thwaite & McKay, 2013; Veen & de la Croix, 2017). The majority of studies done in science classrooms focus on all classroom discourse rather than just student to student discourse specifically (Adams & March, 2015; Alfonseca et al., 2006; Christodoulou & Osborne, 2014; Griswold et al., 2017; Mestad & Kolstø, 2014; Polman & Pea, 2001; Rivera Maulucci et al., 2014; Roth, 2009; Smart & Marshall, 2013; vanZee & Minstrell, 1997; Varelas et al., 2013; Venville & Dawson, 2010; von Aufschnaiter et al., 2008; Wellington & Osborne, 2001; Young & Talanquer, 2013). There are several studies on the university level that looks at student to student interactions in online class forums (e.g., Alfonseca et al., 2006; Uzuner Smith & Mehta, 2013) rather than active face to face talk. A few studies are similar to the current study but vary on details (de los Santos, 2011; Hsu et al., 2009; Puntambekar et al., 2021; Watters & Diezmann, 2016). The current study will examine the application of student-student dialogue in the science classroom and analyzes how students are talking when they talk about physical science in laboratory activities.

Theoretical Framework

Several theorists and researchers (e.g., Alexander, 2008; Brown, 2016; Egglezou, 2016; Lemke, 1990; Mercer, 2004; Mercer, Dawes, & Staarman, 2009; Vygotsky, 1978) support the use of dialogue and conversation in the classroom to improve students' ability to construct knowledge and gain content understanding. For instance, Vygotsky and Bakhtin argue for the inclusion of discourse to build knowledge among those engaged in the dialogue (Bakhtin, 1981; Vygotsky, 1978). Friend (2017) explains that there are six vital functions of classroom talk: thinking, learning, communicating, democratic engagement, teaching, and assessing. Following Friend's idea, productive conversations would be achieving one or more of these functions.

In looking to the science classroom literature specifically, things like evidence-based argumentation, effective questioning, and the effective use of the language of science are all hallmarks of productive conversation (Chin & Osborne, 2008; Colley & Windschitl, 2016; Duschl, 2008; Duschl & Osborne, 2002; Osborne et al., 2013; Osborne & Chin, 2010). The U.S.

National Research Council even has called to having productive conversations at the heart of current science education reform (NRC, 2007; 2012).

Part of the use of scientific language is a piece of the idea of Big “D” Discourse and little “d” discourse. Little “d” discourse is any form of communication, not just “conversations” between two parties. Dialogue is specifically between two interlocutors who are co-constructing meaning and is part of general discourse. Sociolinguist Paul Gee (2014a; 2014b) articulates the difference between “discourse” as a form, and “Discourse” as a Stance. Little “d” discourse simply is language-in-use, Gee (2014a; 2014b) describes big “D” Discourse as language-in-use, as well as all the accouterments of a discipline. So, in the lab, the Big “D” Discourse is not only the use of scientific terms but also the scientific tools and actions being used. Big “D” discourse therefore is a viewpoint that includes the little “d” discourse as well as the philosophies and tools of the subject. The students would likely be participating in and developing the Discourse of Science when making hypotheses, or taking measurements, or drawing conclusions based on experimental evidence and discussing these, as well as when they are using a Bunsen burner or caliper. The distinction between D/discourse will be discussed further in Chapter II.

Bakhtin described a similar concept of *social languages*. According to Bakhtin, a social language is “a discourse peculiar to a specific stratum of society (professional, age group, etc.) within a given social system at a given time” (Bakhtin in Holquist, 1981, p. 430). Sacks, Schegloff, & Jefferson (1974) explain “talk is socially organized, not merely in terms of who speaks to whom in what language, but as a little system of mutually ratified and ritually governed face-to-face action, a social encounter” (p. 679). This idea is also like *social languages* in that it acknowledges the presence of social requirements. Both explanations of social languages are reflective of the language-in-use portion of Gee’s (2014) Big “D” Discourse.

Looking at the needs of the student and based on constructivist and sociocultural perspectives, discourse allows the student to develop knowledge and skills, such as metacognition and effective communication. The language-in-use needs to be productive and varied to rationalize the inclusion of student-student conversation. Student-to-student dialogue can provide a wide variety of conversations in which students can participate, which should include the Discourse of the subject. If, per Dewey's (1916) claim that "education is . . . a fostering, a nurturing, a cultivating, process" (p. 12), then a "learning-centered" classroom using productive talk between students is a way to cultivate students to educate them.

Sociocultural Theory and the Role of Dialogue

Learning occurs where learners have to actively construct meaning rather than passively acquire it (Chin & Osborne, 2008). Vygotsky's sociocultural theory also makes a case for the importance of dialogue in the classroom. He believed that all development occurs twice: "first on the social level, and later, on the individual level; first between people (interpsychological), and then within the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and the formation of concepts" (Vygotsky, 1978, p. 57). So, to develop concepts, a student must have interactions with others to move the knowledge from interpersonal to intrapersonal. Meaning making, and thus learning, is a socially constructed outcome. Students need to have social interactions to move concepts into their knowledge.

Knowledge requires construction, and in the case of the dialogic classroom, co-construction while working with a mediator. This co-construction of knowledge allows students to appropriate the scientific concepts of school subjects (as described by Vygotsky, 1978; here it means all formal knowledge). It also is important for students to spend time in dialogue using the Discourse of the subject with their peers to practice the co-constructed knowledge.

The Role of Discourse in Meaning-Making

Bakhtin worked in literary criticism and in his view, dialogue was a crucial element in discourse of any kind. Therefore, a dialogue occurs between two interlocutors who are co-constructing meaning. He saw all language as a dialogue between the writer/speaker and the reader/listener. He argues that "*any true understanding is dialogic in nature*" (Bakhtin in Morris, 1994, p.35, emphasis in original). If this is true, then having a dialogic form of teaching will improve students' understandings. Schwarz and Shahar (2017) make the point that, based on Bakhtin and Vygotsky, there is a need for reflective discourse. Reflective discourse, they say, is exploratory talk containing elements of reason and critical thinking (Schwarz & Shahar, 2017). This type of discourse can be instituted in a classroom through the promotion and teaching of productive student dialogic exchange, the offering of opportunities to engage in argumentation, and through the fostering of inquiry rather than the accumulation of discrete facts or formulas.

Mortimer and Scott (2003) also use Bakhtin's idea of the use of multiple voices to argue that meaning-making in science is a dialogic process, and it requires learning a *social language* or Discourse. To learn science, students must learn the language of science and practice it. This confirms Lemke's (1990) point about students needing to practice "talking science" (p. ix). Mortimer and Scott (2003) also propose that students must learn two social languages to learn science, one is the language of science and the other is the language of school science. Productive use (defined in Chapter II) helps students practice using the language of science.

These ideas of *social languages* and Big "D" Discourse point to the need for using language in the science classroom to appropriate the content into useful knowledge for the student. Student-student dialogue will allow for the practice of using the language and promote being a critical reader and speaker of science content.

Purpose of the Study

The purpose of this study is to examine student-to-student dialogues occurring in a physical science laboratory to understand better what types of dialogue the students use while engaged in laboratory activities where student-to-student discourse is usually encouraged. A more extended period of recording will allow for students to become accustomed to being recorded and thus engage in the kinds of "real" dialogue that can be analyzed as opposed to something "performed" for the researcher. The use of laboratory activities allows for long periods of uninterrupted student dialogue during which the students are naturally required to have dialogue to achieve the goals of the experience. Ideally, while the teacher is present and can be consulted if needed, he/she will not be a significant contributor to the conversations, nor does she guide the conversations overall. The conversation occurring leading up to the students' requests for help may also prove interesting in the overall patterns of the conversations. This study will report the interactions during the laboratory time to assess what types of dialogue are being used as the students use reasoning to conduct the experiment and learn from the activity.

Significance of the Study

The significance of the study is found in the insights provided into peer-to-peer discourse in this physical science laboratory setting; such discourse likely also occurs in other science classrooms. Using discourse analysis, characteristics which leads to the constitution of productive conversation will be identified and could possibly be included in teacher education programs. Such information will help fill the gap in the literature on how to assess the use of student-to-student dialogue in science classrooms and overcome the "idle chatter" problem (Alexander, 2020b).

To meet current science standards and to meet the demands of the curriculum (*Next Generation Science Standards*, 2013), students should be actively participating in discussion in the classroom. In *Next Generation Science Standards* (NGSS) (2013), there are suggestions that students should be "doing" science. Science, in part, is "done" inside the conversations of scientists through the process of peer-review and face-to-face discussions, so students need to experience a variety of dialogue using the language of science. The NGSS recommendation aligns with sociolinguistic theories of discourse. With the NGSS's current focus on hands-on and inquiry-based learning in science, there should be consideration of how these styles of learning influence the nature of discourse patterns.

Research Questions

This project will address the following research question:

1. What are the patterns of talk in student-to-student discourse in laboratory activities in a 9th-grade physical science laboratory setting?
2. Is there any relationship between the patterns of talk and the nature of the laboratory activity?

Overview of Research Methods

The researcher applied a qualitative grounded theory approach (Charmaz, 2006) and the research questions were considered using Discourse Analysis (DA), as described by Cazden (2001), Gee (2014a; 2014b), and Rymes (2016), as a tool to analyze the data. Discourse Analysis is a method designed to engage in the analysis of actual dialogue to determine what social roles, meanings, and statuses are continually being negotiated through face-to-face conversations.

The basic premise of Grounded Theory is to begin with as few preconceived notions about the topic as possible, acknowledge the ones that are present and build a theory based upon the data that emerges from the research at hand (Brown, 2010). The prior notions found to be in existence for this study will be presented in Chapter III, as well as the reflexivity of the researcher. However, it is important to note that this project has been in development for several years and will most likely continue for several more. This study is to be the first portion of the progressive study of student-to-student conversations in science classrooms and will probably generate more questions than answers at its conclusion. This project is intended to be continued; this is just one progressive stop on the journey to identify the importance of conversation in the classroom.

Using the DA in conjunction with a grounded theory methodology allows for the close analysis of the student-student conversations to reveal information about the negotiation and construction of meaning using everyday conversation between interlocutors (i.e., the students engaged in dialogue). In this close analysis, it is possible to gain insight on the student's perspective of conversations during class by intently listening to the content of the students' conversations and well as analyzing how the conversations are delivered.

Definitions

In this study, students engaged in laboratory activities that involved students in different ways including 1) building components to analyze (hands-on instruction), 2) testing chemicals for their identity (by flame and by precipitate; hands-on instruction), and 3) engaging in a computer simulation. Here these terms are defined.

Computer Simulation

In science instruction, computer simulations are used for various activities, such as teacher illustration of a topic to the whole class or as a laboratory activity (defined below) for students (as seen in this study). “In science and science teaching, simulations are useful only if they accurately show the phenomenon in question and/or produce the same results that would otherwise be obtained by doing the actual investigation” (McComas, 2014, p. 18). Researchers have found a positive result on student achievement when computer simulations have been used (Geban, Askar, & Ozkan, 1992).

Hands-on Instruction

This refers to “instructional activities that give students the opportunity to directly explore, investigate, and/or observe, probe or manipulate objects or scientific phenomena” (McComas, 2014, p. 45). In this study all labs except one where hands-on experiences for the students. They were allowed to manipulate materials and observe the resulting phenomena (i.e., burn a chemical powder to see the colored flames). This term is very general and can refer to any activity that uses the senses to engage, which includes a wide variety of possible skills and activities. It has more recently been called “hands-on/mind-on” due to the desired result of increased engagement in the subject, but there is definitely a continuum of potential activities from “cut and paste” (little “minds-on” required) to writing and performing a science lab.

Laboratory Activities

Laboratory activities, such as above, are when science investigations are carried out within the classroom. These activities, usually referred to as labs, sometimes be called “practical work.” They could be either a “dry” lab or “wet” lab and could involve a wide range of student choice in making decisions in conducting the lab. A “dry” lab is when the “activities are those that do not use real laboratory equipment but simulate aspects of the actual observation or experiment either using technology or paper and pencil or cut-out materials” (McComas, 2014, p. 56). A “wet” lab is when “investigations are the more traditional laboratory exercises that do permit students to use real laboratory equipment to investigate phenomena and explore nature” (McComas, 2014, p. 56).

Assumptions

The following assumptions apply to this study:

1. The teacher has taught the students how to have productive conversations before the study being conducted. The teacher has a tendency toward dialogic pedagogy.
2. The labs are understandable and will produce accurate outcomes for the majority of students.
3. Language is essential, and the nature of language is invisible.

Limitations of the Study

There are some limitations to this study:

1. Due to the qualitative aspect of this study and the nature of grounded theory, it was challenging to have more than a few student groups in the study. However, the idea was to gain insight into student-to-student conversation so that further study can be done for larger samples.
2. For this study, the age, gender, and number of years of experience of the teacher were not considered; the only consideration for the teacher was to verify

laboratory time was used for student discussion, and the teacher led a typically dialogic classroom.

3. The selection of the class to observe was chosen in a non-random manner. This was due to the need for a classroom that was using student-to-student dialogue and contained students that had already been taught to handle the conversations in the classroom and the availability of permission for administration and teachers.
4. The structured nature of laboratory activities may affect the students' verbal interactions differently, based on the open- or closed-ended nature of the lab.
5. The students and the teacher were required to change school buildings in the middle of the study, which may have influenced the nature of the discussions after the move because of new laboratory settings.
6. The beginning of the COVID-19 pandemic occurred during the final labs that were recorded, and with the closure of schools, no further data was able to be recorded.

Delimitations

Limitations on the internal validity of the study include:

1. Results will be limited to those students who chose to participate in the study. This leads to problems with generalizability because the students may not be representative of all students in the classrooms.

CHAPTER II: REVIEW OF LITERATURE

Introduction

In this chapter, the definition of dialogic teaching will be presented and expanded before discussing the key components of productive talk as has been studied to this point. There will be a review of the literature on these, and *Social languages* and D/discourse will be defined and clarified as to their meaning for this study. After this discussion, this review clarifies what is meant by "productive talk" and defines student-to-student productive talk (SSPT). Next, a discussion will be offered concerning its use in the classroom to promote student conversation and learning. Other concepts, such as argumentation, small group work, laboratory activities, will be considered for their prospective role in student conversation and how they are linked to SSPT and dialogic teaching.

Friend (2017) explains that there are six vital functions of classroom talk—thinking, learning, communicating, democratic engagement, teaching, and assessing. Talk is variously defined and, in Friend's study, is defined as primarily one person speaking while all others are listening, whereas dialogue (seeking exploration or resolution of a particular subject or problem) and conversation (informal exchange of ideas) are representative of two or more voices in concert with one another. However, the functions mentioned by Friend lend themselves to talk, conversation, and dialogue equally. Alexander (2020) agrees, and thinks that talk, conversation and dialogue are sometimes conflated unnecessarily, and adds:

> it is also true that recent years have witnessed a broadening of the observable repertoire of classroom talk among both teachers and students – with, for example, paired and small group discussion taking their places alongside whole class interaction, and teachers showing greater readiness to switch between these. More strikingly, in a significant number of classrooms, and sometimes across whole schools and local authorities

> there are now teachers who give high priority to talk in one, two, three or indeed all of the senses previously described and use it with rigour and flair and to impressive effect (p.20).

Teachers use conversation, dialogue, and talk in their classrooms to encourage students to understand and form conclusions about the content. Allowing student conversation gives the students ownership of the content. Barnes (1976) discussed talk and its place in the classroom, as well as the importance of student-to-student dialogue to refine thoughts and ideas before having to produce ‘final draft’ talking, or to provide a generally polished and final answer to the problem that has been presented. Barnes discusses the value of allowing students to talk through confusion in a manner that seems to be disorder or disarray to come to a general consensus. He considers this to be a productive and valuable process. Mortimer and Scott (2003), discussing science learning specifically, explain:

> It is through talk that the scientific view is introduced to the classroom. Talk enables the teacher to support students in making sense of that view. Talk enables the students to engage consciously in the dialogic process of meaning-making, providing the tools for them to think through the scientific view for themselves. (“Does Science Classroom Talk Matter?” Para. 4)

Craddock (2017) explains that evidence supports the need for discourse in the classroom, and current instructional strategies do not provide adequately to prepare students to be scientifically literate. Craddock points to Cazden (2001) for the need for conversation that fulfills the aforementioned vital functions. The importance of student-to-student discourse is that it gives educational access to all students (e.g. Jay et al., 2017; Kelly et al., 2017; Moore, 2007; Warren et al., 2001) and provides opportunities to the students to share ideas, receive feedback, and learn more about other perspectives.

Regardless of content, students need to have experience using the ideas and tools of science to appropriate them into the student’s knowledge. In an analysis of classroom dialogue of elementary students learning science, Watters & Diezmann (2016) explain that more experienced teachers allow more student-to-student interaction and that in less experienced teachers' classrooms, peer-to-peer interaction is more rare. Craddock (2017), considering a phenomenological study of elementary teachers who teach science as opposed to science specialists, agrees with Watters & Diezmann's findings, and expresses the need for better teacher and administrator preparation to increase the occurrences of student-to-student talk. In a study of discussion in high school project-based learning, Alozie et al. (2009) state that spontaneous science talk is rare and, therefore, must be taught. They also explain that the years of acculturation that high school students may have gone through will limit these discussions as well, which points to an even more definite need to establish appropriate training for teachers. However, if educators are to use this valuable tool effectively, it needs to be clearly defined so that proper curriculum can be created, and proper assessment can occur.

How the students construct knowledge through conversation is the main interest of this study, and student-student dialogue will be considered in depth. Vygotsky (1978) suggested that learning is co-constructed through discourse with others. Vygotsky's sociocultural theory makes a case for the use and importance of dialogue in the classroom. For students to develop concepts, they need to have interactions with others to move the knowledge from interpersonal to intrapersonal. Further discussion of sociocultural theory and dialogue will be presented from the perspective of Vygotskian scholarship, Bakhtinian influence will be considered as well.

Dialogic teaching is one solution offered to provide the necessary opportunities for co-construction of knowledge. Alexander (2020) defines dialogic teaching as "both talk and more than talk, for it enacts a dialogic stance on knowledge, learning, social relations, and education itself" (p.1). Since dialogic teaching can be a precursor of productive talk through its design of encouraging dialogue amongst all classroom participants, having insight into SS talk will allow for future development of better official materials that will promote the production of such talk.

Why Dialogue is Important to Student Learning/Understanding

Vygotsky and Bakhtin both studied the effect of social and cultural influences on humans. Vygotsky studied education specifically. However, Bakhtin's work was not focused on education specifically, but it has found a place there through his views on dialogism and the idea that all understanding is dialogic in nature, belonging both to the speaker/writer and to the listener/reader. Bakhtin did his work in the field of literary criticism however, in his view, dialogue was an important and key player in discourse of any kind. He saw all language as a dialogue between the writer/speaker and the reader/listener. He argues that "any true understanding is dialogic in nature" (Bakhtin in Morris, 1994, p.35, emphasis in original). If that conclusion is to be supported, then having a dialogic form of teaching will improve students' understandings.

Vygotsky's socio-cultural theory also supports a case for dialogue in the classroom. He believed that all cultural development occurred twice: "first on the social level, and later, on the individual level; first *between* people (*interpsychological*), and then *inside* the child (*intrapsychological*). This applies equally to voluntary attention, to logical memory, and to the formation of concepts" (Vygotsky, 1978, p. 57). Therefore, to develop concepts, a child needs to have interactions with others to move the knowledge from interpersonal to intrapersonal. Barnes (1976) also echoed these ideals of Vygotsky and Bakhtin. In his book, he points to socio-cultural learning ideals and the need to build communities of learning that allow for student exploration of school subjects in particular, but also in understanding the world around them and how our society works.

Mortimer and Scott (2003) also use Bakhtin's concept of discourse to make their argument concerning meaning making in science. They believe it is a dialogic process and it requires learning what Bakhtin called a *social language*. According to Bakhtin, a *social language* is "a discourse peculiar to a specific stratum of society (professional, age group, etc.) within a given social system at a given time" (Bakhtin, in Holquist, 1981, p.430). To learn science, students must learn the language of science and practice it. This confirms Lemke's (1990) point that students need to practice "talking science." This idea of *social languages* points to the need for using language in the science classroom to allow students to appropriate the content into useful knowledge. Dialogic teaching will teach the practice of using the language and being a critical reader and speaker of science content.

"Learning is a generative process requiring effort in which learners actively construct their own meaning that are consistent with their prior ideas rather than passively acquire knowledge transmitted to them" (Chin & Osbourne, 2008, p.3). Knowledge requires construction, and in the case of the dialogic classroom, co-construction while working with a mediator. This co-construction of knowledge allows students to appropriate the scientific concepts (as described by Vygotsky, 1978; here it means all formal knowledge) of school subjects.

Kozulin (2003) discusses co-construction of knowledge in terms of a human mediator, the person involved in an activity before it can be internalized. A student must experience activities through the mediation of others. While this function is usually filled by a more knowledgeable person it may be filled by a peer, though Kozulin (2003) admits that the parameters of human mediation were "too numerous and context-dependent to allow for a simple classification" (p.19). Whomever the mediator may be, the mediation of development of concepts is needed for the student to appropriate the concepts. This mediation can be provided through the discourse of the classroom, including student-student dialogue. Through the use of student-student discourse, students can gain internalization of concepts (Brown, 2016; Reznitskaya & Gregory, 2013; von Aufschnaiter et al., 2008). This will require the use and development of *social languages* and D/discourses in the classroom.

The need for effective discourse in the science classroom is also important to meeting goals in documents like Next Generation Science Standards (NGSS, 2013). Dialogic teaching is a method that can be used to achieve this; however, dialogic teaching is more common in English classrooms than science classrooms. However, using Bakhtin's and Vygotsky's ideas for education and applying those concepts in science classrooms can change that.

Dialogic Teaching: Definition and Impact

Dialogic teaching has been proven useful in many areas such as English and Social Studies instruction (e.g.; Boyd & Markarian, 2015; Haneda, 2017; Jay et al., 2017; Reznitskaya, 2012; Rogers et al., 2006). There have also been studies on dialogic methods to use in the science classroom, including argumentation and inquiry, which will be discussed further later in this review. As with many things in education, dialogic teaching appears on a spectrum, a teacher can have dialogic tendencies but not fully embrace dialogic teaching. To move toward a more dialogic stance which is supported by theorists such as Vygotsky and Bakhtin, there is a need to further study the use of dialogic strategies such as student-student dialogue.

Alexander (2008) made the case for dialogic teaching in the classroom in general rather than just a certain subject. He defines dialogic teaching as:

> *collective*: teachers and children address learning tasks together, whether as a group or as a class.

> *reciprocal*: teachers and children listen to each other, share ideas, and consider alternative viewpoints;
>
> *supportive*: children articulate their ideas freely, without fear of embarrassment over ‘wrong’ answers; and they help each other to reach common understandings;
>
> *cumulative*: teachers and children build on their own and each other’s ideas and chain them into coherent lines of thinking and enquiry;
>
> *purposeful*: teachers plan, and steer classroom talk with specific educational goals in view (Alexander, 2008, p. 38).

Alexander (2008) describes student-student (in his words, “pupil-pupil”) dialogue as children listening carefully to one another, encouraging one another to participate and share ideas, building on their own and each other’s thoughts, striving to reach a collective understanding and agree on conclusions, and having respect for minority views. Reznitskaya and colleagues (2012) explain that in a dialogic classroom the teacher is *in* authority, rather than *the* authority like in a typical non-dialogic classroom. Students and the teacher share authority, have a perspective of shared inquiry, and the teacher tends to ask divergent questions (Nystrand et al., 2003).

Hajhosseiny (2012) also discussed the characteristics of critical thinking: analyticity, systematicity, inquisitiveness, open-mindedness, truth-seeking, and maturity. These criteria and characteristics are the evidence of productive talk in the classroom. Hajhosseiny (2012), in their study of the effects of Dialogic Teaching on students’ critical thinking dispositions, explains that critical discussion (such as what occurs in dialogic teaching classrooms) motivates students to experience mental challenge and makes education more dynamic. Hajhosseiny (2012) also found that these critical discussions helped students to be a part of social interactions more often and to be able to gain more from those experiences, such as knowing each other, friendship and intimacy, cooperation, tendency to dialogue, responsibility, and class dynamism.

Alexander's 2020 book continues to support this definition of dialogic teaching; however, he adds that dialogic teaching is more than just "classroom talk." "It is as distinct from the question-answer and listen-repeat routines which most of us experienced in school as it is from everyday conversation, it aims to be more consistently searching and reciprocal as both" (Alexander, 2020, p.1). He goes on to say that "dialogue takes us beyond classroom transactions into the realms of ideas and values, for dialogue is as much a stance or outlook…as it is a pedagogical technique" (Alexander, 2020, p.1-2). "Dialogic pedagogy emphasizes the idea that dialogue *is* learning, not merely a means to learning" (White, 2015, p. 36).

Students who are not comfortable using the standardized language of the classroom (typically WASP upper middle-class dialect) to do this generating of knowledge may find it difficult participate in discussions. "Dialogic pedagogy classrooms may. . . be scary or unsettling places for learners who have grown accustomed to receiving rather than generating knowledge" (White, 2015, p. 41). Bakhtin addresses this with a discussion of dialogic pedagogy and the responsibility of the instructor. In a 1945 essay, he offers this useful point. He says:

> language has a powerful effect on the thought processes of the person who generates it. Creative, original, exploratory thought that is in contrast with the richness and complexity, of life, cannot develop on a substrate consisting of the forms of depersonalized, cliched, bookish language. Further fate of a student's creative potential, to a great extent, depends on the language he takes with him out of high school. And this is the instructor's responsibility. (Bakhtin, 2004, p. 24)

This only furthers the need for dialogic teaching to assist the instructor in their responsibility to their students. Assisting the students to overcome the discomfort of generating knowledge is a key to effective dialogic pedagogy and uses teacher agency to further this goal. However, it is not just the teacher's agency that matters in the classroom.

Dialogic teaching, unlike the traditional lecture-style teaching, is not only about the agency of the teacher but also the agency of the student. Agency comes with responsibility so the character of the talk matters whether it be teacher talk or student talk. And student talk is where students use language to make meaning of the world and the content of the classroom. Agency is students taking ownership of their education, and dialogic teaching and its strategies encourage the growth of that agency. One of the ways this happens is through "productive talk" which will be further defined later. First, the idea of *social languages* and D/discourse will be discussed.

Social Languages and the Kinds of D/discourse

Bakhtin's concept of a *social language* plays a role in the students' abilities to talk about the practice and identity of science and make connections. A *social language*, according to Bakhtin, is "a discourse peculiar to a specific stratum of society (professional, age group, etc.) within a given social system at a given time" (Bakhtin & Holquist, 1981, p. 430). Therefore, for students to talk about science, they must have the social language of science as a part of their repertories.

Concerning *social languages*, Bakhtin (2004) discusses the idea of the language portion of Gee's Big "D" Discourse. Gee (2014a) suggests this little "d" discourse is the language used and the big "D" Discourse consists of that along with the various other "stuff" that makes up the whole Discourse. In the case of science, its language, and tools, along with the "trappings" of being a scientist, such as laboratory equipment or a lab coat, are included. Discourse includes Bakhtin's *social language* idea as well as the tools that can be used to enact that language. "Discourses are not units or tight boxes with neat boundaries. Rather they are ways of recognizing and getting recognized as certain sorts of *whos* doing certain sorts of *whats"* (Gee, 2014b, p. 184). Using Discourse as the conceptual frame rather than *social language* alone allows for full analysis of situations where the conversation may or may not be enough to explain or identify the type of *social language* used. Examining the implementation of the use of specific tools around the conversations can promote this. For example, knowing the setup of the laboratory activity can help define what is happening inside of conversations around the lab.

It is necessary to consider all Discourses in which the students may participant, such as their Discourse as a "Student" or as an "Athlete." These other Discourses should be acknowledged in the context of the dialogue as they may affect how the students talk and how they connect the concepts of science. For example, a student using the "Athlete" Discourse may use the *social language* of sports to make connections to the concepts. These other Discourses are part of the *communicative repertoire* of the student, which will be the building blocks of the development of his/her own identity as a scientist. Big "D" Discourses can also be used to help the students make connections, and they encompass the practices of science.

Little "d" discourse, according to Gee (2014a), is language-in-context or language-in-use.

> When linguists study language-in-use and use the term "discourse" for this – they are concerned with the relationship between language and context, with the ways in which contexts help determine the full extent of what we mean or can be taken to have meant. (Gee, 2014a, p. 20)

This language-in-use is examining the connection between sentences, among and across them. This type of discourse is mostly what Bakhtin was discussing when speaking of *social languages*.

Dialogue is the content of the conversations in which people are involved using their *communicative repertoires*. In this study, dialogue will refer to the conversations of the students amongst themselves, between two or more students, with the primary goal being to build understanding and/or solve a problem.

Difference between D/discourse and dialogue

What is the difference between dialogue and discourse? Are they two different things entirely, or are they two words that can be used interchangeably? Depending on the scholar, the answer seems to be yes to both of those questions, but that is not satisfactory for this study. In physical science laboratory settings, this is a distinction that needs to be established to identify productive conversations as those to be described below. Student-to-student talk is a part of the Discourse of the science classroom and can be in the form of dialogue, though not always. Dialogue is the actual exchange between specific interlocutors, whereas discourse, or language-in-use, is the broader collective sense of how various speakers address or think of physical science in general.

Big "D" Discourse is different from little "d" discourse because discourse is language-in-use. Big "D" Discourse is, as Gee (2014a; 2014b) suggests, a tool of inquiry. Little "d" discourse is an "interactive identity-based communication using language," and big "D" Discourse is "*both* language and everything else at human disposal" (p.24, emphasis in original). Discourse as a tool of inquiry allows the analyst to identify the *social language*, identities, and practices that the participants are using to build their world, in language, as well as reality.

In this form, Discourse is very different from dialogue and language-in-use and can include, but is not limited to, dialogue. This shows that dialogue is a part of language-in-use, but not *all* of language available, because of this, Discourse and dialogue will not be used interchangeably.

In this study of physical science laboratory settings and student-student dialogues, the distinction is potentially significant, particularly the distinction between Discourse and dialogue as part of the language-in-use. The Discourse that teachers hope their students will be using in a science classroom is that of science (Gee, 2014a; Lemke, 1990), but perhaps that is not yet part of the *communicative repertoire* they use when in conversation with one another. Their dialogue here may point to the use of other Discourses, such as possibly a Discourse of "academic study," or Discourse of "school science." Distinguishing these different possible Discourses may be necessary for analyzing the dialogue of students.

"D/discourse theory is about seeing interactive communication through the lens of socially meaningful identities" (Gee, 2014, p.25). The socially meaningful identities here are related to being a student of science, so the interactions should include things like wonder, curiosity, and questioning, as well as an understanding of safe lab practices and procedures and efficient techniques. Gee (2014a; 2014b) also points out that in order "to say, do and be something," a person needs other people and things. Therefore, D/discourses are socially constructed and are a negotiation between the speaker and the world of things and others. Without the references provided by the world, a person could say, do, and be something. However, there would be no meaning to it.

Sacks, Schegloff and Jefferson (1974) explain that "talk" is a social interaction which is a "little system of mutually ratified and ritually governed face-to-face action" (p. 679). This idea of talk as something that is social in nature and has an agreed upon yet not explicit set of rules also links to Gee's (2014) idea of Discourses. Talk and D/discourse has an agreed upon meaning but the explanation of those meanings is not taught. Therefore, *social languages* must be acquired through use. In a dialogic teaching classroom, students are encouraged to explore different Discourses, practice their use, and eventually add to their own *communicative repertoires*.

Rymes (2016) discusses the fact that everyone has a *communicative repertoire* or "a collection of ways individuals use language and other means of communication (gestures, dress, postures, accessories) to function effectively in multiple communities in which they participate" (p. 9). Also, Wertsch (1991) used the idea of a toolkit made up of the Discourses of the speaker. This repertoire, or toolkit, uses multiple Discourses to create the language the students will use in class; however, the students may not yet have the language of the discipline (i.e., science) in their repertoire. Therefore, they need to use connections, practices, and identity to add science-speak to their repertoire. Alexander (2020) even makes repertoires the center of his framework and connects to the functions of classroom talk mentioned in the opening of the chapter. He points out however that “the other side of the repertoire coin . . . is *agency.* But dialogic teaching…aims to liberate the voice and thinking of the student, so in the dialogic classroom agency is indivisible, and the imperative of acquiring and internalizing options applies to the student too” (p. 133) not just the teacher’s use of their agency in the classroom.

Communicative repertoires are defined as language-in-use which adds an important element to understanding how they function. Knowing a word is different from understanding when it is appropriate to use it. Rymes (2016) uses the example of the word *dude*, explaining “having a full command of *dude* means knowing the word and being able to use it within context-knowing, for example, that you might say it to your friend but not your grandmother” (p. 25). Connecting this to Bakhtin’s formulation that all words are populated “with the intentions of others” (1982, p. 294), a word is also subject to interpretation of others once spoken. Having command of the word *dude* in the *communicative repertoire* means knowing how to use it, but also to make sure others understand its use. This idea expands to phrases as well.

Concerning the ideas of *communicative repertoire* and a toolkit of *social languages*, Gee (2014a) considers as a tool of inquiry big "D" Discourses as it allows for the determination of the types of *social languages* that are in use by looking at the accouterments and other contexts of the language-in-use. This big "D" Discourse tool of inquiry will be useful in the discourse analysis of physical science students because the Discourse of science is a way for students to build identity as a scientist. Also, it is necessary to consider the students' full *communicative repertoires*. The Discourse Analyst's investigation needs to encompass enough of the context of the language-in-use to conclude that persuasive arguments can be made. These other parts of the *communicative repertoire* should be acknowledged in the context of the dialogue as they may affect how the students talk. For example, a student who is in the "Gaming" Discourse may behave or talk differently than a student in the Discourse of "Music Enthusiast" in a student-student dialogue. These other Discourses are part of the *communicative repertoire* of the student, which will be the building blocks of the development of their own *identity* as a scientist. The full *communicative repertoires* can also be used to help the students make connections and encompass the practices of science.

If the student successfully appropriates the Science Discourse, he will hold a greater sense of connection to the *identity* and *practices* of science. So, considering the Discourses available to the students will help to recognize the *practices*, *identities*, and *connections* (Gee, 2014a) they make, or do not make, in their student-student dialogue. Using the methods of discourse analysis (DA) as explained by Gee (2014a; 2014b), Rymes (2016) and Cazden (2001) allows a researcher to look at the naturally occurring talk between interlocutors to establish patterns, thus establishing the *communicative repertoires* available to the students. Entities such as cadence and tone contribute to the identification of the *communicative repertories* and the patterns discussed later help establish these as well whereas more formal patterns like *I-R-E* tend to lend themselves to a more school science repertoire. An open conversation may have a different repertoire in use or may point to a more hybrid repertoire in use. Establishing the *communicative repertoire* is done through the conversation itself, through various notations on tone and cadence but also with the *building tasks* suggested by Gee (2014a; 2014b). DA will allow for some conclusions to be drawn about the types of conversation in which the students are participating and determine the critical aspects of that dialogue.

The Nature of Scientific Discourse

Gee (in Yerrick & Roth, 2005) expresses the need for students to practice the language of science and other academic languages. He says, "children need to be able to produce, not just consume, academic forms of language and, thus, must not just learn about them, but acquire some degree of control over them, at least enough to write and speak them in school" (Yerrick & Roth, 2005, p. 43). This verifies the need for practice in the classroom, and that practice is best done in S-S conversation, rather than a classroom setting where the teacher delivers the information, and the students passively consume.

Lemke (1990) discusses the need for students to practice "talking science" in the classroom. He studied the talk in science classrooms and found much talk happening in the science classroom; however, only seldom did the students do the talking. He was the first to thoroughly examine and analyze classroom discourse in science (de los Santos, 2011). Except for cross-discussion (when a student was talking out of turn to another student for clarification or off-topic), students only got to talk science when called on by the teacher in a standard Initiate-Response-Evaluation (IRE) format. Furthermore, in those cases, there was sometimes not even a requirement to answer in complete sentences. From Lemke's study, it is clear that students were not practicing their science talking skills.

Lemke (1990) concludes that students need practice in "talking science" (here he means the Discourse of school science which is distinct from the Discourse of science; however, he does not use the D/discourse terminology), and the state of the classrooms he studied did not lend themselves to that practice. In dialogic teaching, dialogue allows for the practice of "talking science," either between teacher and students or between students. This practice will allow for students to learn the *social language* of science (Holquist, 1981). "The one single change in science teaching that should do more than any other to improve students' ability to use the language of science is to give them more practice actually using it. Students must be given opportunities to speak at greater length (in monologue and dialogue) . . ." (Lemke, 1990, p. 168).

These conclusions verify a need for dialogue in the science classroom, particularly student to student dialogue. Students need the opportunity to use the language of science to develop their knowledge of the subject. There are many ways to allow the students to use the language of science; one of the ways is through student-to-student discourse on which this study will focus. "One of [Lemke's] most enduring ideas is that *learning science is learning how to talk science* (which includes observing, describing, comparing, classifying, analyzing, discussing, hypothesizing, questioning, challenging, arguing, judging, evaluating, etc.)" (de los Santos, 2011, p. 9, emphasis in original).

De los Santos (2011) also explains that if language is a resource for meaning making, then it is reasonable to assume that students must *use* the language of science to make meaning in science. School science has a variety of highly particular language practices that hold sway. Lemke (1990) suggests that teachers and students are encouraged to avoid colloquial language;

figurative language; emotional, colorful, or value-laden words; hyperboles; exaggeration; stories; humor; as well as personalities and reference to human beings and their actions. Society often tells students that scientific talk "should be impersonal and expository, and that development in the discipline involves moving away from any roots in personal or emotional response" (Ballenger, 1997, p. 18). If sociocultural situated types of speech that students bring to school are not valued, "then students receive the message that the ways they make sense of the world are not important and not to be brought to bear on school learning" (Ballenger, 1997, p.2). Therefore, we must know and acknowledge the other Discourses of students. The recognition of the students' other Discourses is important because of the student's need for their identity to be acknowledged and valued, which encourages dialogue.

Defining Identity and Authority

Identity

> People tell others who they are, but even more important, they tell themselves and then try to act as though they are who they say they are. These self-understandings, especially those with strong emotional resonance for the teller, are what we refer to as identities... In this continuous self-fashioning, identities are hard-won standpoints that, however dependent upon social support and however vulnerable to change, make at least a modicum of self-direction possible. They are possibilities for mediating agency (Holland et al., 1998, p. 3-4)

Identity is ambiguous: "it is what you can't help being, but also what you choose to become" (MacCabe et al., 2018, p. 187). Erikson, as cited by MacCabe, claims the study of identity becomes strategic in our time. He argues that "psychosocial identity develops out of gradual integration of all identifications . . . here, if anywhere, the whole has a different character from the sum of its parts" (MacCabe et al., 2018, p. 186). "The core meaning of identity for

Erikson remained in the tradition of Locke: 'the ability to experience one's self as something that has continuity and sameness'" (MacCabe et al., 2018, p. 184).

The word *intersectionality* references the insight that race, class, gender, sexuality, nationality, etc. give to the claimed identities of humans. These identities do not operate as "unitary, mutually exclusive entities, but rather as reciprocally constructing phenomena" (MacCabe et al., 2018, p. 187). In the classroom, identity can be assumed by the expectations of others based on appearances or previously developed ideas of the student, however the student's actual chosen and/or developed identity may not be visible but can be "seen" through other means. As Gee (2014a; 2014b) discusses, identities can be a complex concept and consist of a complex set of practices including *social discourses*. So, through attention to a student's choices in many areas, a teacher or researcher can make assumptions about the identities they are embodying. And those identities can influence the student's participation in class and how they respond within conversations.

"Consider this paradox: While a *communicative repertoire* is unique to each individual, an individual's 'identity,' built through interactions with others" which is a social construct, so "one's identity, or *the kind of person one appears to be*, is constructed through how *other people* encounter that person" (Rymes, 2016, p. 20) So identity is also socially constructed and interacts with the *communicative repertoire* and language of the individual to form a solid base from which the individual can stand and hold some type of authority and agency.

However, Schiffrin (1994) points out that social identity can be viewed "as a category of social life and conduct that is subject to locally situated interpretive activity" (p. 235). And then proceeds to point out that "the relevance of a social identity can be no more presumed to hold across different times and places than can the relevance of a one second pause" so it embodies a changing and interpretive aspect. It is built within the context of the situation of the speakers and the language-in-use, and thus can constantly be in development. “Language, as preeminent social practice, is inseparable from identity. We use talk to do things and bring all manner of objects, including ourselves and others, into being” (Lee, 2012, p. 38). A student can gain a part of their identity in the moment of the conversation and thus gain agency and/or authority that is given to them by their cohorts.

When a specific identity is strong, it will provide a sense of agency in the person. Agency is the feeling of being able to act and have the action accepted by others as legitimate. Someone with agency can seem to be in control, or have authority, and most classroom authority is held by the teacher. But “the meaning and function of classroom discourse is built from social and interactional texts as well as individual agency” (Rymes, 2016, p.49) which includes the individual agency of all classroom actors. In this quote, Rymes is referring to “texts” in a DA manner meaning this is applicable to all words in the form of written or spoken within the context of the classroom. For a classroom to encourage the development of students’ identities as a scientist, the teacher must share the authority and allow for the student’s agency in science to grow.

Holland et al. (1998) explain this with the concepts of *figured worlds* and *identity-in-practice*. *Identity-in-practice* accounts for the social construction aspect of identity and its intersection with free will. *Figured worlds* are “historical subjectivities, consciousness and agency, persons (and collective agents) forming in practice” (Holland et al., pp. 41–42). Lee (2012) explains these worlds are “imagined or ‘as if’ locales that have recognizable social architectures (e.g., teenage romances), figured worlds motivate people to action, existing in a dynamic interplay with identities and human agency” (Lee, 2012, p.37). These *figured worlds* allow for students to act and have agency to practice science in the classroom, which leads to the practice and use of authority.

Barton et al. (2013) discuss the idea of *identity work* being a more fruitful option of study since *identity* itself is in a constant flux and is very subjective to both the person carrying the identity and the others who are labeling others with an identity. Such as one student may identify themselves as a "good student", but their teacher may define them as "average." With the use of studying *identity work* the researcher can look to the D/discourse, *social languages*, *communicative repertoires*, and other markers of the classroom such as established norms and practices of the system studied to determine what identity a student is working toward or authoring for themselves.

A part of building an identity in any subject or system is becoming a part of the larger community that has been built around the topic or subject. These Communities of Practice (CoP) play a critical role in the real world and enforce group norms that allow for the authoring of an identity based on the CoP. They consist of groups of people with a purpose or common goal to accomplish, though it may be challenging to discern accomplishments, the participation is voluntary, unlike a team where one is assigned a place (Baker & Beames, 2016). The idea of establishing clear CoP has been taken up in education, particularly in nursing education (Baker & Beames, 2016). CoPs, as tools for student learning, are starting to be recognized in K-12 education as well.

Lave and Wenger (1991) address CoP and its place in schools. In school,

> there are vast differences between the ways high school physics students participate in and give meaning to their activity and the way professional physicists do. The actual reproducing community of practice, within

> which school children learn about physics, is not community of physicists but the community of schooled adults (p. 99).

However, the community of schooled adults allows for students to participate in a specific Discourse, and within that Discourse, the Discourse of physics or science can be practiced as well, since the CoP of Schooled Adults can include the more specific CoP of sciences. However, as schooling continues and more science is learned, the students slowly join the CoP of physics or chemistry, thus acquiring and participating in the Discourse of physics or other physical sciences. As they acquire the identity of a science person, they step into the chosen CoP for whatever science identity that they are invested in receiving. This could be a community of school science, a community of schooled adults interested in science, or even a community of science enthusiasts who like to do science as a hobby, as well as the more formal community around a specific type of science.

Hughes and colleagues (colleagues (2021) discuss the importance of building identities in science as well as in various CoP around learning science. They define "science identity development as opportunities wherein individuals develop and/or strengthen competence in science, perform these competencies, and are recognized by perceived experts for these performances" (p.422). Discussing specifically girls in science, but also mentioning challenges of people of color in science, they suggest that the ability to build these science identities becomes harder when society does not support girls or people of color as scientists. The idea of girls losing interest in science and math in the middle school years is highly developed and studied and this could be because the societal version of "scientist" is typically a white man in a lab coat. When building an identity for oneself it is considerably easier when the student sees themselves in the overall accepted identity. Therefore, girls and people of color potentially find it more challenging to develop a science identity.

Once an identity is established, no matter what that identity may be, a student may find themselves in a position of authority in certain conversations and classroom discussions. Therefore, *identity* and *identity work* are important to understand in order to see how authority is yielded in student-student talk.

Authority

> The Latin noun *auctoritas*, from which English **authority** is complexly derived through varieties of medieval French, has wide range of meanings: right of ownership, sanction, approval, resolution, advice, right or power to authorize, leadership, authoritativeness, weighty testimony, precedent, example, prestige, personal influence, esteem, repute. These meanings blend in and out of each other in a particularly complex history in which **authority** plays a key role in regard to both knowledge and power (MacCabe et al., 2018, p. 23).

"In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual" (Galileo, as quoted by MacCabe et al., 2018, p. 24). This thought signified the increase in emphasis on reasoning and experimental method and less on written texts or even experts. This change leads to the idea of authority through power rather than knowledge, though they overlap some in the forms of an educator's or parent's authority over children. The educator's authority is based on the idea that they know the content and how to deliver it in a comprehensible manner, however it also is a form of power in that they also control behaviors in the classroom. For students to have authority, it must be sanctioned by the teacher in most classrooms. However, in dialogic classrooms the power of authority is often spread between all participants somewhat more evenly than in teacher-centered classrooms.

Authority in the classroom is usually wielded by the teacher who is seen as an authority due to their status of educator. Authority figures as defined in the OED are "any person[s] regarded as having authority" and "it applies to a government agent, a policeman, an educator, or a parent" (MacCabe et al., 2018, p. 25). However, students can assume authority in some classroom situations, particularly when they are working together in small groups. One student may take on the position of discernment of correctness, thus assuming an air of authority amongst the group. This authority of knowledge is seen in the common phrases such as "to have it on good authority" or "on the authority of" but since the Renaissance this type of authority is provisional, other students may question the authority of the students who are claiming it through talk and/or actions.

Students can also borrow authority by using "the *voice* of science" or "the *voice* of reason." Both represent an authority outside of the student and sometimes even outside of the teacher or the classroom. Usually when this type of authority is borrowed, other participants in the conversation may shut down or not respond well to the use of this type of authority. Or they simply comply with whatever was said because they trust the authority of these *voices* from outside the group even if they do not recognize authority within their fellow students.

Authority, whether earned or borrowed, can provide agency also. Agency is a sense of "personal control, the ability to act in ways that produce desired outcomes or contribute to our own personal projects. Having personal control seems straightforward enough. But, as we have discussed, social and interactional contexts control us far more than we usually notice" (Rymes, 2016, p. 43) and thus the student's identity comes into play. Even if the teacher shares authority, the student must have an appropriate identity to have agency and use the given authority.

Authenticity is also a part of this dynamic with identity and authority. If a student carries an appropriate identity and authority, but is seen by others as inauthentic, then it may be difficult to convince others to accept their identity and/or authority in the given situation. Wallace (2004) suggested there are multiple types of authenticity in the classroom, but when it comes to authentic communication (the most interesting for this study), the students need to use scientific language to express their own experiences. He states:

> The authentic use of language will involve the appropriation of academic scientific discourse into everyday language. It follows that the more the child's everyday experiences mirror the experiences of those who use academic science (scientists), the higher will be the appropriation of scientific language into authentic communication (Wallace, 2004, p. 903).

This kind of authenticity, or lack of it, may be why when students borrow authority from other *voices* (in this case the *voice* of science), their fellows may not accept what they say because they are not using the *voice* authentically which causes the others to not trust the student's authority. However, if the student can show suitable appropriation of scientific language, not only do they borrow authority from science, but they also add to their own authority in science.

Another link to authenticity is the use of students' own everyday language in order to appropriate scientific language. Warren et al. (2001) points out that when students' own language is not encouraged in classroom or science work, it can lead to a barrier to students' learning and cause a devaluation of the experiences they do and can bring to the science classroom. Warren and colleagues also point out that it cannot be assumed that jokes and personal experiences of students, or the use of everyday language, lack intellectual substance or are outside of what counts as science. And that doing so can hinder the authentic talk of students because the students will be uncomfortable by having to use a more formal and stiff language that is somewhat expected as scientific talk. Citing Ballenger (1997), Wallace explains:

> [Ballenger] asserts that the cultivation of vernacular language use in science class can lead to rich thinking about science and represent less threatening forms of instruction for students of nonmainstream sociocultural backgrounds. Vernacular language is certainly authentic to children and is the obligatory starting place for appropriating scientific language use (Wallace, 2004, p. 904)

This also points to the need for authenticity in the communication of science and the science classroom.

Defining Productive Talk

Looking to the *Framework for K-12 Science Education* (2012) and related *Next Generation Science Standards* (2013) for guidance, this study seeks to establish the need for the use of dialogue in the science classroom in the United States. Page one in Appendix M starts with the line, “Literacy skills are critical to building knowledge in science” (*Next Generation Science Standards*, n.d.) and goes on to explain how the CCSS in English should inform and coincide with the development of NGSS-based science curriculum. NGSS has specific recommendations regarding the use of dialogue and argumentation in the science classroom. These documents state that students should be evaluating claims, evidence, and reasoning of various scientific ideas, as well as producing evidence and reasoning for their claims. Citing the National Research Council’s work from 2007 & 2012, Colley and Windschitl (2016) report that “The call to engage students in productive talk is now at the heart of current science education reforms” (p. 1010).

In science classrooms, productive talk could be evidence-based argumentation, effective questioning from both teacher and students, and the use of the Discourse of science. Several researchers have examined and refined what is meant by “productive talk” in the science classroom including (Chin & Osborne, 2008; Colley & Windschitl, 2016; Duschl, 2008; Duschl & Osborne, 2002; Osborne et al., 2013; Osborne & Chin, 2010). In these studies, scholars analyzed student questions, argumentation, and the role of discourse in learning science. Other studies focus on productive talk in any classroom environment and its place in building understanding. All of these contribute to the formulation of a definition of productive talk in the science classroom.

Argumentation and its Role in Productive Talk

Learning through engaging in scientific inquiry (which is different from general inquiry; in that, it follows the processes of science rather than just curiosity) addresses the epistemic goals that focus on how we know what we know and why we have faith in our beliefs. This type of learning promotes the reasoning of why the beliefs of science are more fruitful than other ways of knowing, such as religion or philosophy (Duschl & Osborne, 2002). Wenning (2009) discusses the epistemic nature of science and how "science teachers need to understand the types of arguments that scientists use in actual practice to sustain the subject matter that they claim as knowledge" (p. 3). This allows the teacher to guide productive conversation in the classroom. Many researchers (Chin & Osborne, 2008; Colley & Windschitl, 2016; Duschl, 2008; Duschl & Osborne, 2002; Osborne & Chin, 2010; and Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013) in science education point to the use of argumentation and inquiry in the classroom and argumentation and inquiry can use a form of dialogic discourse for students to actively build understanding of concepts in the science classroom.

Wenning (2009) also explains that empiricism uses logic with evidence to lead to knowledge. It is often the question "how do you know?" that scientists ask and argue the answers to build scientific knowledge. This leads students to understand that science, though based on observation and experimentation, is socially constructed (Driver et al., 2000). This helps the student to see science-in-the-making, rather than a set of hard facts. That science is "in-the-making" needs to be understood, so students and the public have a more authentic view of what science is (Driver et al., 2000). Discussing the appropriation of scientific concepts through learning activities, Giest (2003) acknowledges the noticeable shortcoming of science instruction from its "dominant orientation toward isolated, non-situated facts, which are seldom applied to real-life situations" which leads to "difficulties in understanding and a loss of sense and motivation in many students" (p. 267). A way to combat this shortcoming is to provide learning opportunities contrary to this dislocation of facts.

In the development of Activity Theory, an extension of Vygotsky's sociocultural theory, scholars suggest that *learning activity* is essential to the appropriation of science concepts. A *learning activity* is

> a special kind of human activity developed during societal development as an important aspect of human culture that has to be appropriated by individuals in order to be used, then, for concrete learning goals that depend on learning motives, objects, and conditions (Giest, 2003, p.269).

It is a teacher's role to guide students to gain the necessary activities to use when learning science. One such activity would be productive argumentation. Another would be inquiry learning.

Argumentation is different from the idea of "fighting" or defending one's point of view to the exclusion of all others. This lay definition of argument must be addressed before students can participate in productive argumentation (Duschl & Osborne, 2002; Felton, Garcia-Mila, Villarroel, & Gilabert, 2015; Kuhn & Dean, 2004). Some may call it "discussion" or "debate" to avoid the confusion of the lay definition of argumentation. Alexander (2020) asserts:

> For the purposes of lexical definition, [he has] treated argumentation as a form of dialogue. Yet argumentation may be voiced or silent, an oral encounter or an intellectual one, a meeting of people, ideas, or both, so equally it can stand apart from dialogue as talk. For while argumentation may benefit oral interaction, it does not in every case require this (p. 37).

The type of argumentation suggested here is also treated as a form of dialogue, it is used as more of a conversational tool that allows multiple viewpoints to be considered together; it is a *learning activity*. Therefore, it must be taught and the implementation of it learned to be useful in the classroom.

Mercer (2004) considers the conversational nature of joint construction of knowledge. “Conversations are founded on the establishment of a base of common knowledge and necessarily involve the creation of more shared understanding” (Mercer, 2004, p.139-140). What Mercer calls a conversation involved with this type of argumentation is what needs to happen in the science classroom. While not all conversations are argumentative, the idea of building common knowledge and a shared understanding is the goal of productive argumentative talk.

Effectively to analyze the arguments, Mercer (2004) points out the need to focus on the functions of conversation in the pursuit of joint intellectual activity. This joint intellectual activity requires goals to be set and achieved. Persuasive debating, or “fighting” for one view over all others, limits the achievement of those goals and the ability to revise understandings (Felton et al., 2015). Also, Felton and colleagues (2015) explain that there is “evidence that discourse goals affect the degree to which individuals learn the content of the arguments they discuss” (p.374). This can affect how students participating in classroom argumentation will be able to gain understanding of the content. The goals of productive talk should be for the student to gain understanding of the content presented ultimately.

Osborne and Chin (2010) discuss the role of argumentation in science and the need for students to interact with one another rather than just the apparatuses of science. Lemke (1990) says that talking science does not mean merely talking *about* science, but rather it means *doing* science through the medium of language and argumentation is a way of *doing* science. “‘Talking science' means observing, hypothesizing, describing, comparing, classifying, analyzing…" (Lemke, 1990, p. 1) as well as many other actions such as arguing and making conclusions. "All these actions are facilitated by asking students to engage in discursive argumentation and a dialogic process or interactions between student and student (as opposed to the more common interaction between teacher and student)" (Osborne & Chin, 2010, p. 92).

This student-to-student argumentation is a part of the productive talk defined above. Argumentation requires critical and constructive engagement for the students to co-construct knowledge, as Mercer (2004) describes. Students must engage one another and produce cognitive conflicts to make each other consider the ideas they have about science. This helps to make the students' thinking visible (Colley & Windschitl, 2016; Duschl, 2008; Duschl & Osborne, 2002). Mortimer and Scott (2003) express the need for more talk in the science classroom to encourage meaning making, they refer to this as a dialogic process "which always entails bring[ing] together, and working on, ideas" (p. 11).

Students must be exposed to multiple Discourses and various viewpoints and learn to negotiate between them (Byhring & Knain, 2014; Felton et al., 2015). These Discourses require authenticity and a situated common ground that allows students to incorporate the new Discourse of science into their repertoire. The authenticity offered by argumentation is useful for this negotiation of learning science. The teacher can give students a common ground by relaying what Mortimer and Scott (2003) call the *scientific story*, the story of science that pulls school science into a picture of how science is done in the real world. If this story is told well, the students will be able to place their arguments into the broader framework or Discourse of *real science*. The *scientific story* is a part of the overall Discourse of Science.

> It is the role of science education…to expose the criteria by which [scientific] evaluations are made and explain how those criteria are themselves justified—a task which can only be done if argumentation occupies a central, rather than peripheral position in the values of the science educator (Duschl & Osborne, 2002, p.45).

Once the idea of arguing to be "right" is addressed, discursive goals are set, and the scientific story is in place, argumentation, and the dialogue that accompanies it can create an atmosphere that allows for the co-construction of knowledge. Again, productive talk plays a vital role, as well as the presence of cognitive conflict, to allow students to appropriate the needed science content. Argumentation also plays an essential role in inquiry, a key to science.

Duschl & Osborne (2002) state that argumentation in science is necessary to align with the epistemic, or knowledge-based nature of science. They also point to the fact that if teachers are not allowing students to engage in inquiry (here this means a generally inquisitive nature of the students), they are not allowing for the construction of knowledge in any classroom, but especially in science classrooms. Having dialogue and argumentation in the classroom helps support reasoning, *doing* science, and learning *about* science. This puts the locus of inquiry with the student rather than the teacher, as found in the standard I-R-E format discussed above (Duschl & Osborne, 2002).

Argument is a kind of "quality control" in science; it is how scientific knowledge is built (Driver et al., 2000). Therefore, using argumentation in the classroom provides authenticity to the experience. Moreover, an authentic experience is key to productive and accountable talk and student engagement. Duschl & Osborne (2002) also point out that this type of inquiry and argumentation encourages the development of communities of practice, the presence of which is vital in *real science*. Building communities of practice, as discussed above, within the science classroom also leads to a more authentic experience.

If all the tools, structures, and grouping techniques are in place to lead to productive conversation or epistemic discourse, then the discourse leads to understanding and meaningful knowledge construction in a discipline. Vygotsky (1978) believed that knowledge was co-constructed with others through social interaction and then internalized. Therefore, all the strategies and structures should guide students to co-construction and appropriation of content.

However, some studies show that this does not always occur. In some cases, students will display their knowledge rather than co-construct it, or they will only speak when they feel they have the "correct" answer (Clarke, 2015). In other cases, a discussion can be ideologically dialogic (taking multiple POV) but discursively non-dialogic (just one speaker) (Aguiar, 2016; Ford & Forman, 2015). These problems should be considered so the teacher can step in and guide the discussions back to the productive dialogic conversation. One step that can be taken to accomplish this is using follow-up rather than evaluative feedback, which can lead to a more dialogic stance (Nassaji, 2000). Teaching the students how to provide follow-up questions or feedback rather than evaluative feedback should be considered and modeled. One unclear thing is the type of feedback that students provide each other.

Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson (2013) point out that a growing body of studies suggests that argumentation can lead to better conceptual understandings and help increase critical thinking. Kuhn and Crowell (2011) also found that dialogic argumentation seems viable for developing cognitive skills that do not typically develop in middle school. Arguing is a human practice (Driver et al., 2000), and a valuable one in science. Kuhn (1962) stated, "the decision to reject one paradigm is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature and each other" (p. 78) This is why argumentation in the science classroom is important. Students need to learn how to compare scientific information and think critically about it.

Multiple Points of View and their Role in Productive Talk

While there are empirical studies about dialogue in the classroom, not many have reached conclusions about assisting students with the acquisition of content knowledge. Some studies discuss argumentation and its ability to improve reasoning and metacognitive skills (Brown, 2016; Howe, 2010; Kuhn & Crowell, 2011; Osborne et al., 2013; Rivera Maulucci et al., 2014; Venville & Dawson, 2010) And there is an occasional study that looks at content as well (Reznitskaya & Gregory, 2013; Webb et al., 2009) though one was inconclusive (Osborne et al., 2013).

In a review of 40 years of research in this area, Howe and Abedin (2013) found many studies on student-student discourse that report a richness of student contribution that does not appear in the I-R-F format discussions, but they do not elaborate on content knowledge. Furthermore, Kuhn (2000) explains, “we lack sufficient research observing individuals engaged in the process of acquiring new knowledge” (p. 180). However, there are studies on argumentation and its benefits (Brown, 2016; Chin & Osborne, 2008; Howe, 2010; Kuhn & Crowell, 2011; Venville & Dawson, 2010; von Aufschnaiter et al., 2008), though some are inconclusive (Osborne et al., 2013; Reznitskaya et al., 2012). The inconclusive studies focus more on the transfer of skills and understanding.

The Howe and Abedin article acknowledges that dialogic interaction is explicitly conceptualized as considering several points of view and depends not on holding back evaluative feedback but providing non-evaluative feedback to each other, thus allowing the conversation to continue. The only way to get multiple points of view is through discussion with multiple people. Alexander (2020) points out that "all such reviews, comprehensive—in the case of Howe and Abedin—though they may claim to be, are selective, some inexplicably so" (p. 51) (though Alexander believes Howe and Abedin explain their selectivity well). However, he also points out that Howe and Abedin conclude that there is a shared conceptual core with divergence around the edges on the topic of productive talk and classroom dialogue.

Student-to-student discourse can promote the ability of students to make sense of the knowledge gained in the science classroom. In responsive and productive talk, students build on each other's ideas and can make their thinking visible to others (Colley & Windschitl, 2016; R. Duschl, 2008; R. A. Duschl & Osborne, 2002). The students are responsive to the ideas and thoughts being voiced in the conversation. Colley & Windschitl (2016) warn that these types of conversations take time to build. The conversation may start shallow but improves with practice. This need for practice is why a classroom needs to have students using conversation as a classroom tool from the beginning of the school year.

Brown (2016) explains that exploratory or productive talk leads to generalizations, communicative struggles, and co-construction of knowledge. It is also significant to open up dialogue and create space for argumentation, a key to student-student dialogue in the science classroom that will be discussed later. She also explains that productive talk uses the students' language to allow them to construct knowledge. This is important because allowing the dialogue to occur in their speech helps make the topic familiar to the students.

Elizabeth, Ross-Anderson, Snow, & Selman (2012) discuss a similar type of talk called accountable talk. There are three facets to accountable talk: "accountability to the learning community, accountability to standards of reasoning, and accountability to knowledge" (p.

1220). These ideas easily fit with productive talk, since productive talk has an element of accountability concerning the dialogue in the classroom. Elizabeth and colleagues continue by stating that "accountable talk holds students responsible for the integration of their own reasoning and knowledge with that of their peers" (Elizabeth et al., 2012, p. 1220). Accountable talk overlaps and is thus part of productive talk.

Cognitive Conflict and Decentering and their Role in Productive Talk

Piaget (1932b, 1932a), a proponent of S-S dialogue, discusses the need for cognitive conflict to establish meaning and develop one's own opinions and knowledge. This cognitive conflict leads students to a better understanding of content; however, this only happens if they are exposed to conflicting ideas. Student-student dialogue allows for such ideas to be presented and thus dealt with by the students (Webb, 2009). Citing multiple other sources, Webb explains that these sources combine to illustrate

> how socio-cognitive conflict, the production of different cognitive approaches to the same problem that emerge during social interaction, leads to progress when a student takes into account his perspective while considering another's incompatible viewpoint. Confronting others' contradictory ideas may involve explaining and justifying one's own position, with the positive attendant effects on student learning (Webb, 2009, p. 3).

Moon, Stanford, Cole, & Towns (2017) also discuss the idea of decentering, a way of characterizing a person's effort to understand how another's position differs from their own. Decentering is based on Piaget's theory of child development and the idea of cognitive conflict. It only applies when multiple views are being shared and are also crucial in cognitive conflict as it is a way of processing the information that caused the conflict in the first place.

Howe (2010) explains that a two-way relation is evident between peer dialogue and cognitive growth, citing the same cognitive conflict ideas of Piaget (1959, 1965). Howe (2010) explains there is evidence of a well-researched connection to the value of interactions involving children expressing contrasting opinions in pursuit of a common goal, and this connection is enshrined in the concept of exploratory and productive talk. However, students must find a way to resolve any conflicts productively. Resolutions may occur during the discussion for older students, but for younger students, resolutions may be delayed by days or weeks (Howe, 2010). This delay could be due to the developmental stage in younger students' brains; it simply takes longer for them to process thoughts. Howe (2010) also found in the literature that the more opinions and conflicting information presented in the dialogue, the better the results on post-test answers, no matter if the resolution came during or after discourse.

Mercer, Hennessy, & Warwick (2017) define productive talk as a discussion that everyone engages in critically and constructively, offers relevant information, all ideas are treated with consideration, students ask questions and answer them, students ask others for reasons and give reasons when asked, the group tries to reach agreement, and to an outsider of the conversation reasoning is "visible" in the talk. Regardless of what student-student dialogue may be called, there is a commonality in research that holds to the idea of the use of productive talk in the classroom, and it can and should happen between students. Colley & Windschitl (2016) recognize that "relevant resources (knowledge) of all kinds must first be activated and then collectively refined and revised over time through purposeful activity and discourse" (p. 1013).

Aguiar (2016) in a discussion of Rocksén (2016), points to the key features of utterances: sequentiality (Bakhtin's idea that every utterance is interpreted by other utterances that came before); joint construction of meaning (meanings are established by interlocutors about what a word means and the criteria of its use); and dialogism (dependence of the communicative processes of the broader aspects of the activity). One way to achieve these dynamic and intricate utterances is in a joint mediated activity using language as the semiotic basis of understanding. Again, the need for practicing "talking science" arises.

Productive conversation should have the hallmarks of evidence-supported statements. These statements should have the students building on and supporting one another's comments. The students should be making their thinking visible in the flow of the conversation; a level of accountability should be established between one another in the development of the conversation. Still, most of these studies look to teacher-student dialogue rather than student-student dialogue, which is the gap this study is trying to fill. All these aspects of productive talk should be present in the student-student dialogue; however, how what appears may be different than they appear in teacher-student dialogue, which is what this study will address.

Types of Conversations and their Role in Productive Talk

Although this type of productive talk is recommended and even needed in the science classroom, many researchers find the persistence of the common Initiate-Response-Evaluate (I-R-E) or Initiate-Response-Feedback (I-R-F) format being used in classrooms (Alozie et al., 2009; Cazden, 2001; R. A. Duschl & Osborne, 2002; Elizabeth et al., 2012; Friend, 2017; Howe & Abedin, 2013; Kaya, 2014; Lemke, 1990; Mehan, 1997; Mercer et al., 2009; Mortimer & Scott, 2003; Nassaji, 2000; Watters & Diezmann, 2016). Mortimer and Scott (2003) "assert that science classroom talk matters and that it is invisible; thus, research priority must be to make existing practices visible" (de los Santos, p. 14)

Mortimer & Scott (2003) originally defined the three discourse patterns commonly found in science classrooms; (1)I-R-E or I-R-F or triadic pattern, (2) I-R-F-R-E or closed-chain pattern, and (3) I-R-F-R-(E) where the parenthetical E indicates that is missing at the end of the interaction or open-chain pattern. It seems that I-R-E exchanges are what is commonly used and are most comfortable for all concerned and thus is a difficult cycle to break.

I-R-E conversations, as well as the more extended I-R-F-R-E conversations, shows more authority so it may be unlikely to see as much of these because they depend on the student's identity and authority among their peers. The most found variation was an extended I-R-F-R-E format, in which the teacher gave more general feedback allowing the student to give a second response. I-R-E and I-R-F are not necessarily negative occurrences in the classroom, and sometimes they are beneficial. However, when they are used as the only form of dialogue, and the teacher is the predominant initiator, it becomes a problem (Friend, 2017). Attempting to sustain inquiry and a dialogic stance improves the chances of more productive conversation happening (G. Wells & Arauz, 2006).

Mortimer and Scott (2003) discuss the four classes of communicative approach (see figure 2.1), and while they were discussing teacher-student talk and interactions, there was evidence of these in the student-to-student discussions studied here. It was in examining these dynamics that led to assertion two about the effects of identity and authority for students in the classroom.

	INTERACTIVE	NON-INTERACTIVE
DIALOGIC	**A** Interactive/ Dialogic	**B** Non-interactive/ Dialogic
AUTHORITATIVE	**C** Interactive/ Authoritative	**D** Non-interactive/ Authoritative

Figure 2.1
Four classes of communicative approach (Mortimer & Scott, 2003)

Mortimer and Scott (2003) talk about two talk continua: interactive to non-interactive, and dialogic to authoritative. In this section, the first will be discussed and the second, while needed generally in this section as well, will be explored more in-depth in assertion two. The interactive to non-interactive continuum initially seems clear. On the one end, the conversation has participation by multiple interlocutors and on the other, there is participation by only one speaker. Mortimer and Scott (2003) in talking about teacher-student talk related non-interactive to the teacher talk without participation from students, however it could, on the dialogic-authoritative continuum, remain dialogic in nature. The dialogic in Mortimer and Scott's explanation is not the same as Bakhtin's idea of all things being *dialogic* in nature. In this case, remember that the dialogic talk they refer to can be related by one person recounting a dialogue or by one person sharing someone else's thoughts on a topic, basically attention is paid to multiple *voices* even though it is recounted by just one physical voice. With that perspective, it is easier to comprehend how something could be non-interactive and yet still be dialogic in nature.

Most would consider the non-interactive talk on the other end of the dialogic-authoritative continuum. Authoritative talk is focused on only one point of view, usually the teacher's or the accepted point of view in the subject, in this case, science. When talk is authoritative and non-interactive, the speaker controls all, and does not include considerations for other points of view or *voices* and in the case of teachers, they do not consider any input from the students. Mortimer and Scott (2003) point out that there is rarely talk in the classroom that is both fully authoritative and non-interactive. Usually talk is happening at various points of both continuums. In brief, authoritative/interactive talk is when the teacher asks questions of the students, but then does not take them into consideration in the further development of the talk.

One would expect to see a more interactive and dialogic stance in dialogic classrooms in general, but even more so in student-to-student talk. This is because for there to be authoritative talk, whether interactive or non-interactive, there needs to be a way for the speaker to claim authority. That may be harder for a student to have over other students, but not unheard of, if the student in question has built an identity that lends itself to being an expert in the topic of conversation. This links back to the idea of *identity work* put forth by Barton et al. (2013) and discussed earlier. On the interactive/non-interactive continuum student-student talk may become non-interactive if a student dominates the talk or the ideas being presented. A particularly headstrong student may come to dominate the conversation and thus turn it into a non-interactive and authoritative conversation.

Table 2.1
Summary of Productive Conversation Markers from previous studies of teacher-student conversations

- Multiple Points of View (Alexander, 2008; Howe, 2010; Howe & Abedin*, 2013; Webb, 2009)
- Evidence-based discussion and/or argumentation (Duschl & Osborne, 2002; Howe, 2010; Osborne & Chin, 2010; Wenning, 2009)
- Effective questioning (Wells & Arauz, 2006; Wenning, 2009)
- Building on previous utterances or "visible" thinking (Alexander, 2008; Colley & Windschitl, 2016; Duschl, 2008; Duschl & Osborne, 2002; Mercer, 2004; Mercer et al., 2009)
- More non-evaluative feedback than evaluative (R. Alexander, 2008; Howe & Abedin, 2013)
- Cognitive conflict or decentering (Howe, 2010; Moon et al., 2017; J. Piaget, 1932a)
- Productive resolution (Howe, 2010; Mercer et al., 2009)
- Co-construction of knowledge (R. Alexander, 2008; A. C. Brown, 2016)

Additional Components that were in single sources

- Activation of prior knowledge (Colley & Windschitl, 2016)
- Generalizations (Brown, 2016)
- Communicative struggles (Brown, 2016)
- Accountability (Elizabeth et al., 2012)
- And in science, literate use of the language of science

*represents a compilation of studies

Defining Student-to-Student Productive Talk

Student-to-student productive talk (SSPT) is distinct from the productive talk defined above because it is solely between peers. While one peer may hold a higher status identity, the students are on more equal footing with each other rather than the power differential presented when the teacher is involved in the conversation. It stands to reason that all the qualities of productive talk would or could be present in SSPT, however there is one key difference, editing of language.

When a student talks to a teacher, they realize the teacher is looking for a specific type of answer, so the students will internally edit their thoughts to produce the “correct” answer. That revision process is often unseen in these interactions, however, in SSPT there is less need for this revision process to be hidden. Students will try things out, see how things sound, and “play” with ideas when talking to fellow students that they would not do when seeking to produce a correct answer for the teacher. Barnes (1976) points this out in his book. When students talk to one another they have the opportunity to figure things out in a way that is not available in a monologic classroom.

In this study, the markers of productive talk from the previous literature were considered in deciding if the student-to-student conversation captured was productive, but the process of exploring options, self-editing, or peer-editing was important as well. In this case, seemingly *off-topic* talk might have proven fruitful in the overall conversation. When students talk to one another they may seem to be making what seems to an outsider or an adult as unrelated comments, however those references may cue a thought in themselves or their classmates that opens the conversation to a whole different level of understanding. This is where Discourse Analysis proves useful.

Discourse Analysis: Analysis of Talk and Dialogue

> Classroom discourse analysis could be paraphrased as "looking at language-in-use in a classroom context (with the understanding that this context is influenced also by multiple social contexts beyond the classroom-" This lofty addition introduces a "critical" component to classroom discourse analysis. Once we are more aware of how context affects discourse, we can work to change those features of talk that may be inhibiting full participation for all students (Rymes, 2016, p. 8).

To analyze the discussions students have in the classroom, discourse analysis (DA) can be used to systematically reveal the significant features of the peer-to-peer conversations. There are several approaches or methodologies that fall within DA (e.g., Speech Act Theory, Pragmatics, Ethnography of Communication, Conversation Analysis). Methods from discourse analysis (DA) will be used do this. One approach that seemed suitable for this study was Discourse Analysis as explained by Cazden (2001), Gee (2014a; 2014b), and Rymes (2016) as these methodologies explicitly look at the data from conversations and look for patterns occurring in conversations to explain how social order is maintained and meaning making is accomplished through everyday linguistic exchanges. Some of the ideas from conversation analysis did help define some aspects of the DA used, so a brief discussion will prove useful.

Clift (2015) discusses CA concerning the different approaches associated with discourse analysis in general. She explains that CA is at its most straightforward based on *action* and *sequence*. She notes the similarities and differences between CA and Relevance Theory. Relevance Theory goes beyond the code of the language and pure linguistics. It seeks clarification of context to determine meaning. "Context is, for Relevance Theory, a set of assumptions used in the process of utterance interpretation" (Clift, 2016, p. 20). Ultimately, what is most relevant to the participants in conversation is the sequence in which the utterance is said. Whereas an outside viewer of the linguistic code may find structural ambiguity, the actual participants within the context of the sequence in place will most likely not encounter the ambiguity themselves.

To analyze these data, the idea of an adjacency pair, which connects with *action* and *sequence*, needs to be considered. “One of the primary tools driving interaction, from [Classroom DA] perspective, is the adjacency pair, a two-part interactional sequence in which the first part (e.g., a question) produces the expectation for the second part (e.g. an answer)” (Rymes, 2016, p. 38). The adjacency pair is what allows for the identification of the cadence of the conversation. One conversation is usually made up of multiple adjacency pairs, but the idea that there is an utterance with a responding utterance allows for identification of endings of conversations. This was particularly important in this study as conversations were sometimes open-ended rather than displaying a clear evaluative ending, as explained in the types of conversations discussed previously.

There have been studies that looked at how teachers also could change the function of previous utterances based on how they responded. Rymes (2016) explains

> how teachers respond to silences or unexpected answers can change how those answers function as the discourse continues. This ever-present potential for interaction to reshape the meaning of preceding individual utterances is called interactional contingency- How one person’s words function is always contingent on what happens subsequently in talk (p. 41).

This could also possibly happen within student-to-student conversation, so it should be considered as the conversations are coded.

Gee (2014a; 2014b) suggests there are seven building tasks to consider when doing discourse analysis: *significance, practices, identities, relationships, politics, connections*, and *sign systems and knowledge*. These building tasks are what Gee suggests are used to build the

Discourses and Figured Worlds and Situated-Meanings that language-in-use is creating through saying, doing and being. He posits 42 questions divided amongst the building tasks that help in the analysis of the language-in-use. For example, by a researcher asking, "how is this piece of language being used to make certain things significant or not and in what ways" (Gee, 2014, p. 32) they can decide what kind of world the speaker is building. The same happens when looking at *practices* and what they enact or looking at the *identities* or roles that are being filled within the given contexts. By asking these questions, a researcher can ensure a valid study, but also can build a set of hypotheses about the data being studied.

Summary

As mentioned in the introduction, Friend (2017) explains, there are six vital functions of classroom talk—thinking, learning, communicating, democratic engagement, teaching, and assessing. These are the context of discourse. For all the reasons mentioned here, helping students become thinkers and reasoners is the reason for dialogue in the classroom. Because scientists use dialogue and argumentation in *real science*, students need to be doing the same. Dialogue may seem to fit in English or social studies classrooms easily, but it is needed in all classrooms.

Through productive talk and argumentation, students can build understanding. Knowing what students are saying and the patterns that they use in their dialogue with each other will help identify ways to guide students to better understanding. Currently, what students are talking about together is not well studied. Most of the literature in all subjects is based on teacher-student discussion, teacher-whole class discussion, or just teacher talk. This study intends to start to close this gap.

Using DA to analyze the patterns of talk and dialogue can allow for better training for teachers and students to best utilize classroom time. This study can further the work of other researchers who have studied dialogue and argumentation in the classroom by providing insight into what students say to each other when asked to reason an answer together. The study reported here only focused on laboratory activities but could easily be expanded to other times that students talk together.

This study tries to look at the type of labs used and their efficacy in answering RQ2, which can then possibly lead to the production of more effective laboratory activities and provide evidence for teachers to allow more student-to-student conversations where they may not have felt justified doing in the past. Knowing the components and patterns of SSPT discourse can provide a sense of appropriateness to allowing this discourse to happen more frequently and effectively. And lead to the justification the "chaos" of a dialogic classroom.

CHAPTER III: METHODS

Introduction

The purpose of this chapter is to introduce the research methodology for this qualitative grounded theory study regarding what students talk about during lab activities in a physical science laboratory setting. This approach allowed for a deeper understanding of students' experiences while working in groups for lab activities and provided a way to develop theory from the data to understand what patterns were followed. The applicability of grounded theory and a constructivist approach for this study are discussed in this chapter. It also provides the methods used in the study as well as the research questions, the nature of the study, and the timeline. Data reduction will be discussed along with possible issues of validity and reliability.

Grounded Theory Methodology

This study applied a qualitative grounded theory approach (Charmaz, 2006) and the research questions will be considered using Discourse Analysis (DA) (Cazden, 2001; Gee, 2014; Rymes, 2016). Grounded theory is a qualitative way of changing individual knowledge to collective knowledge (Stake, 2010). According to Creswell (2013), using grounded theory allows for the development of a theory that aids in the explanation of a certain practice or provides a framework for further research. This study is intended to do the latter.

This methodology, as explained by Glaser & Strauss (2017), allows for a theory to emerge by methodically coding interviews with terms that succinctly and conceptually summarize each phrase, line, or even word; and then provide a relevant prediction, explanation, or application. Charmaz (2006) and Birks & Mills (2015) both describe the constructivist philosophical position as a view coming from the human experience which is influenced by society, culture, or other external influences and relative to their paradigm. Bryant & Charmaz (2010) point out that grounded theory in educational research complements various forms of qualitative data collection and can make ethnography more analytic, content analysis more focused and interview research more in-depth.

A part of the constructivist tradition is interpretive grounded theory which aims to: "conceptualize the studied phenomenon to understand it in abstract terms, articulate theoretical claims, acknowledge subjectivity in theorizing, and offer an imaginative interpretation" (Charmaz, 2006, p. 127). This research study sought to conceptualize the phenomenon of the students' experiences with conversation directed by themselves, to understand in abstract terms built through coding the data from conversations, acknowledge the subjectivity of the researcher, and construct a theory based on the interpretation of their shared experiences.

Use of DA allows for the close analysis of the student-student conversations and reveals information about the negotiation and construction of meaning using everyday conversation between interlocutors. These methodologies are designed to determine what social roles, meanings, and statuses are continually being negotiated through face-to-face dialogue. Gee's (2014) building tasks questions were considered throughout the various stages of analysis. The building tasks questions for identities, practices, significance and relationships proved to be useful in the analysis. However, Hammersley (2003) explains that neither Conversation Analysis nor Discourse Analysis should be treated as a self-sufficient paradigm. This is why they are used together with grounded theory methodology in this study, which hopefully provided a more focused and in-depth look at the data as Bryant & Charmaz (2010) suggest is possible.

Researcher Reflexivity

I have been in the education field for 14 years. In those years, as a classroom teacher, college instructor, and student teacher supervisor, I have seen and heard many student-to-student conversations, as well as participated in many teacher-student interactions. From the years of experience, it seemed as though the more students talked to one another, their work showed better outcomes. Thus, an interest in student-to-student conversation and its productive place in the classroom was started. At first, I assume that teacher-student conversations were key, but quickly realized that often it was when another student explained a concept that there was an improvement of the other students' understanding.

As with most beginner grounded theory studies, the literature was consulted at various points to verify that there was existing support for this study (Birks & Mills, 2015). Going into this study, I felt that productive conversations were happening in my classroom and therefore happening in other classrooms. The question became how the tenets of student-to-student productive conversation could be defined. These tenets are addressed in the literature review and explains what had been found by others, though most of the cited studies were not on student-to-student conversation alone or at all. From there this study began in earnest, and the pilot study was the first building block to start data collection and analysis. From there, this study evolved and the idea that patterns could be found in student-to-student conversations were developed. After finding a classroom that was run with the Dialogic Teaching style based on the Vygotskian/Bakhtinian framework presented earlier, data collection began. However, the researcher did use simultaneous data collection and coding and tried to limit the effects of preconceived ideas from experience and/or from the literature.

Pilot Study

A pilot study was conducted to see if it was possible to identify productive and unproductive conversations. The format of the recordings was different from the current study, as the students in the pilot study were given a prompt and 5-7 minutes to discuss it within their groups. Of the groups recorded, there were examples of and the spectrum of productive to unproductive talk.

Conversations from the pilot study establish some common identifiable attributes of productive conversation, and the appearance or lack of these attributes can determine the productiveness of the conversation. In productive talk, the comments are connected, the words flow easily, and the participants seamlessly converse, leaving short gaps and only the occasional overlap. When listening to the less productive and unproductive conversation, there was little to no flow. Some statements seemed to appear randomly even though they were on the required topic. In the unproductive conversation, statements appeared to be more of a list than a conversation. There was little to connect the comments one to another.

This flow of discussion can indicate that the conversations will possibly be productive ones. The content of the conversation is what can really mark the productivity. The inclusion of evidence-supported statements that have the students building on and supporting one another's comments is really what leads to productive conversation that could benefit learners, the students should be making their thinking "visible" through the flow of the conversation. These are the markers of a productive conversation that help learners grow and appropriate knowledge of the science classroom and are supported by additional research as discussed in Chapter II.

This pilot study served to set up the initial coding scheme, the development of what would be considered a conversation based on flow and cadence and allowed for the identification of what might be expected in less formal conversations. This was a key part of developing the final coding and categorizing that was done in the full study.

General Features of Study

Context and Purpose

The context of this study is to look at student-to-student academic conversations during labs in a physical science laboratory setting to determine aspects and patterns of talk as well as the content of those conversations. Determining the types, aspects, and patterns of this talk will likely lead to further research into conversation in classrooms and its relevance to learning. The use of discussion in science has been studied, but there are fewer investigations of the specific student-to-student talk in such classrooms (e.g., de los Santos, 2011; Hsu et al., 2009; Puntambekar et al., 2021; Watters & Diezmann, 2016). This study will add a unique perspective to the literature on classroom conversations used by students to co-construct knowledge.

Research Questions

This project will address the following research questions:

1. What are the patterns of talk in student-to-student discourse in laboratory activities in a 9th-grade physical science laboratory setting?
2. Is there any relationship between the patterns of talk and the nature of the laboratory activity?

To answer RQ1, the building tasks of identities, practices, significance and relationships (Gee, 2014a; 2014b) were used to identify patterns in the dialogues during laboratory activities. Using Rymes (2016) ideas of communicative repertoires, context, and agency allowed for further indications of patterns found in the data.

Discussion of Participants and Data Corpus

Due to the qualitative and grounded theory perspective of this study, it was challenging to analyze the conversation of more than a few students in a few groups. In grounded theory there are usually fewer than 20 participants (Creswell, 2013). However, the purpose is to gain insight into student-to-student conversation, leading to further studies using larger samples. For this study, the characteristics of the teacher were not considered (though are discussed below for replication); the only thing required of the teacher was that she used labs and conversation as keys to learning in her classroom. The selection of the class to observe was chosen in a non-random manner.

The Classroom

The ninth-grade physical science classroom studied was in a rural Northwest Arkansas high school. All participants were in the same class period occurring prior to lunch, mid-morning. Each class period was 45 minutes long. The labs were sometimes only a portion of the 45-minute class session, and, in others, the lab was the only activity for the class period. Some labs spanned several class periods depending on what the students were required to do and to precipitate learning. Having all participants in the same period was beneficial because they would have received the exact same instructions and information as the others, thus eliminating a natural variable.

The teacher, Ms. Jones[1], has a Bachelor of Science in Agriculture with a major in Agricultural Education, Communication, and Technology. She also earned her MAT in Agricultural Education. She was finishing her 11th year of public high school level science, including Physical Science, Biology, Environmental Science, Chemistry, Pre-AP Chemistry, and AP Chemistry. She had other teaching experience in adult learning. She felt that she taught in a more Dialogic fashion than in the more traditional lecture style. She taught her students how to use and have productive discussions in her class. The school was reported to have a 60% low-income population in 2017, and a 19% Limited English Proficiency student population. The students in the study were not asked about their income status due to privacy restrictions, but Ms. Jones felt that they were representative of her class population, if not the school's population.

During the school year studied, the high school students and staff moved into a new building, which was expectedly disruptive but did allow for new facilities for the chemistry labs. While there was no disruption to the data collection, it should be noted that the final labs were recorded at the beginning of the COVID-19 pandemic, which was mentioned in a few comments from the last lab activities but was not a significant part of the overall conversation. It did limit the ability to return to record more data, but saturation was met without the use of all recorded sessions, therefore, there was no necessity to acquire more data. Though some of the questions that occurred during processing the data may not be able to be pursued due to this, it did not hinder the reporting here.

[1] Pseudonyms for teacher and students are used to protect participants

The subjects of this study were high school physical science students who were in the classroom of Ms. Jones who used labs to encourage student-to-student conversations and as mentioned above self-identified as teaching with a dialogic perspective. The class was chosen by observation before final selection to determine if student-to-student conversation was present and used regularly for science discussions. The eight participants were self-selected from all classes taught by the chosen teacher. This resulted in an even mix of male and female students assigned to the same class period. This proved useful as it was easy to have groups of 2 or 3 students who all had the same experience as all other groups. There were no ESL students in the groups. All were Caucasian except one who was Latinx.

The Nature of the Four Labs Studied

The four labs studied were from both the physics unit and the chemistry unit of the physical science classroom, and a fifth lab was recorded but not analyzed due to data saturation. Physical Science is an introductory class for both chemistry and physics. Most physical science teachers break their curriculum into one semester focused mainly on physics and one semester focused on chemistry, however there is some overlap of the two subjects when discussing atomic behavior. The labs in the study spanned the semester change with physics being studied in the first semester and chemistry in the second. The one physics lab therefore was after most teaching had taken place, the Atom Simulator lab was a combination of chemistry and physics and provided the transition to chemistry, and the two chemistry labs came at the beginning of the chemistry instruction.

Each session represents part or all the available class time scheduled. Of the four labs analyzed, all but one (the *PhET Simulation*) were actual in-lab experiences. The *PhET Simulation* was a computer simulation from PhET interactive simulations (PhET Interactive

Simulations, n.d.) site created by the University of Colorado at Boulder. The *Levers 'R' Us Lab* is from the Laying the Foundation, Inc., and the other labs were put together by Ms. Jones specifically for her class from various resources. There was a fifth lab called the Pennium Lab that was recorded but did not get analyzed due to data saturation. Copies of the laboratory instructions and worksheets that the students received can be found in the Appendix.

Levers 'R'Us Lab (LRU). The Levers 'R'Us lab allowed for the students to explore first-, second-, and third-class levers. Using various common items, the students are required to build a working version of the three types. Once built, the students took various measurements to prove the change in the needed effort to lift certain loads. The lab had a set of pre-lab questions that had them identify the types of levers in the human body (arms and legs) and the muscles involved. Then after the measurements were taken from the built levers, they had a series of conclusionary questions to answer that required justification for their answers as well as some questions using force equations with different parts to be solved.

PhET Atom Simulation. The PhET Simulation Lab was an atom simulator where students were asked to build various versions of a helium atom and note the changes when electrons, neutrons and protons were added or taken away. They were then to simulate three elements of their choice recording various information such as the atomic number and mass of what they created. In part two, they explored ions and isotopes to see which particles effected certain changes in the elemental atom. For the final part of the activity, there were four games written in the simulation for the students to play and try to achieve a perfect score for each.

Families of Elements (FOE). For the Families of Elements lab, the students were to identify which elements are in the same family based on how they form compounds. The properties of the compounds were observed in a chem plate by placing various ratios of silver nitrate solution with four different solutions of potassium (chloride, bromide, iodine, and sulfide) and noting the ratio that produced the most precipitate. The lab was concluded with comprehension questions about the chemical compounds made as well as possible sources of error and safety rules. This was the first chemistry lab of the chemistry unit, so it was necessary to review lab safety and to acclimate the students in the new laboratory setting in the new building.

Flames Lab. In this lab, the students tested the levels of excitement in electrons of various elements by burning a small amount of the element and observing the colors of the flames. They were given 5 samples of metallic ions (4 known and 1 unknown) which were burned, and the unknown was identified based on the observations of the known ions. The lab was concluded with the students being required to answer comprehension questions as well as give definitions of terms and identify sources and types of error.

Composition of the Three Lab Groups Studied

There were three groups from the 8 students who volunteered from all of Ms. Jones' classes. There was even representation of gender, 4 boys and 4 girls. All participants happened to be in the same class period and were recorded simultaneously by multiple microphones (one for each group). As seen in Table 3.1, Group 1 was made up of two boys and a girl (Andrew, Brian, and Connie), Group 2 was all girls (Dawn, Erin, and Felicia), and Group 3 was two boys (George and Henry). Group 1 and 2 participated in all the lab sessions recorded, however, Group 3 joined the study after the semester change (this was due to the need to gather more data based on the previous data and to test for data saturation), therefore Group 3 was only recorded in the later lab sessions (all sessions for FOE, Flames, and Pennium). All three groups had unique conversations, but as data were analyzed, Groups 1 and 3 were seen to have similar patterns that were audibly and distinctly different from Group 2.

Table 3.1
Group Composition and Pseudonyms for Student Subjects in Ms. Jones's Classes

Group #	Pseudonym of Subjects	# of Sessions recorded
1	Andrew Brian Connie	10 (9 analyzed)
2	Dawn Erin Felicia	10 (9 analyzed)
3	George Henry	5 (4 analyzed)

In table 3.2, the total amount of time captured is noted by group by lab. Notably the times were similar in each lab except for the Atom lab for Group 2. In the 20 minutes that was recorded, they say they will be right back, and the recording stops but there is no recording after this occurs. When comparing the individual recordings of the sessions, it was noted that the times per group were very similar and only varied by a few minutes if at all. This allows for the groups to be fairly compared when looking at the number and times of the conversations, since similar amounts of time was recorded in the sessions that are being compared, as well as the fact that all groups were in the same class period.

Table 3.2
Total Time Recorded for each Lab Studied

	Levers R Us (LRU)	PhET Atom Simulator	Families of Elements (FOE)	Flame Lab	Pennium Lab*
Group 1	1:13:37	48:47	31:27	1:00:15	29:54
Group 2	1:03:09	23:17+	32:27	57:03	29:31
Group 3	X	X	32:19	57:09	28:15

*Not coded because of data saturation, + one of the 2 sessions was cut short and not fully recorded

Timeline

Several teachers were considered before choosing Ms. Jones's classroom. However, the other teachers that were possible participants could not get permission from their administration to do the study, thus their participation was excluded. Ms. Jones was able to get the needed permission from her administration prior to the initial observations. Once the permission was received, I attended two periods of classes, to determine the use of discussions in her classroom. I also had a conversation with her about her general teaching philosophy which included a constructivist ideology and a dialogic stance. The definition of DT from Alexander (2008) was considered as well. Ms. Jones' class showed hallmarks of all 5 qualities of DT (*collective*, *reciprocal*, *supportive*, *cumulative,* and *purposeful*).

The first observations of Ms. Jones's classroom were made in October of the school year after permissions from the school and the teacher were received. The classroom was chosen; the data was collected for each lab performed for November thru February during the one period in which all the students attended. All of Ms. Jones's students were invited to participate, but only the eight students studied chose to fill out the permission slips. It was unexpected, yet beneficial that they all happened to be in the same class period. After the selection of the classroom occurred, Ms. Jones and I planned for the collection of the data. The labs were planned by Ms. Jones according to the district's given curriculum. Over the time of data collection, the class shifted from a physics focus to a chemistry focus. As the data was gathered and appropriately transcribed, data analysis began.

Data Collected

The lab recordings were collected via a thumb-sized USB microphone which was small enough for students to overlook at times. The recordings were transcribed (described in the next section) and uploaded into HyperResearch for analysis. A total of seven hours and 55 minutes of data was recorded over the course of ten class sessions. The ten sessions were divided between five laboratory experiences (see table 3.3 for division of sessions by lab). The three groups each had a microphone at their station recording their interactions. For example, two microphones were employed to record Groups 1 & 2, during the three class sessions required to complete the Levers 'R Us lab (LRU) resulting in the time recorded and noted in table 3.2. For Group 1, the one hour and 13 minutes were recorded over the three sessions of the LRU lab, and the one hour and three minutes obtained for Group 2 was also divided over the three sessions.

Table 3.3
Total Number of Sessions Recorded per Lab

	Levers R Us (LRU)	**PhET Atom Simulator**	**Families of Elements (FOE)**	**Flame Lab**	**Pennium Lab***
# of class sessions recorded	3	2	1	3	1

*Not coded because of data saturation

Discourse Analysis as the Research Tool

To analyze the discussions students are having in the classroom, discourse analysis (DA) can reveal the significant features of the peer-to-peer conversations systematically. There are several "approaches" or methodologies that fall within DA (e.g., Speech Act Theory, Pragmatics, Ethnography of Communication). In this study, DA as presented by Cazden (2001), Gee (2014a; 2014b), and Rymes (2016) will be used to look for patterns occurring in conversation to explain how social order is maintained and meaning making is accomplished through linguistic exchanges. The types and patterns of known aspects of conversation allow for interlocutors to co-construct knowledge through dialogue, and the resulting conversation can be analyzed to determine the possible meanings of these features in the given context. The context and Discourses used make a difference. As Schiffrin (1994) points out, a single utterance can have multiple meanings, and it is the responsibility of the researcher to derive the correct meaning. Various tones and cues noted in DA can help with this derivation of meaning. For example, a question like "do you want a mint" could be interpreted in several ways and, depending on the context of when it is spoken, it could be an offer or an insult, which can only be seen by the analyst within the context of the whole conversation, but particularly by the response that follows.

Turn-taking, false starts, and overlapping speech are a few of the occurrences found in the SS dialogue being studied. The way students initiate, and exchange thoughts could distinguish productive conversation or not. Furthermore, false starts or overlapping speech may show examples of thinking, learning, and/or assessing their thoughts and ideas. By recording at least 10 consecutive minutes of dialogue, it was possible to get a variety of topics and effective, ineffective, on-topic, and off-topic discussions. The key to using DA is that it allows the researcher to assess all the methods available to identify patterns in the various forms of talk. It may be that there will be periods of seemingly off-topic talk that become a learning moment or that follow a learning moment and possibly provide a release value of when learning gets difficult.

Coding and Categorizing

The use of grounded theory requires the development and application of a coding scheme based on the data and literature linked to nature, type, engagement, and other variables noted within the dialogues themselves. Using laboratory activities allows for the development of this scheme since students engage in dialogue with each other during the activities given. The students work together in small groups to create results regarding the concept being taught and most of the conversations are led solely by the students. The peer-to-peer interactions transcribed and analyzed using DA help identify the types of conversations the students have with each other, as well as their productivity that could lead to the change in understanding because of those conversations. And through the grounded theory approach a framework for future study will be developed.

The conversations in this study were recorded over five laboratory activities. Some activities took two or three days of class time. Some took less than a day. All conversations were at least 12 minutes long since only the laboratory work portions of the class were recorded (in some of the sessions the students had some time with lecture before the lab). Upon completion of the conversations, they were sent to transcription. Once transcribed, the conversations were coded in a line-by-line fashion by *turn* and the utterance's overall function during the dialogue. Consequently, the larger patterns of individual conversations were identified and categorized. The categories developed were open-chain, closed-chain, IRE, interruptive conversation, side comment, and teacher help conversations as will be discussed in detail in Chapter III. Once the notations were made, the researcher analyzed the types and times of the representative conversation samples to conclude what the students achieved through their dialogue and identify existing patterns. The achievements of the conversations were weighed against the following conversations as well as typical markers of classroom success (i.e., grades).

Transcription Format. In focusing only on dialogues between students during the labs, Discourse Analysis (DA) was a useful method for the evaluation of these dialogues. Each conversation type was evaluated based on the series of utterances or moves between two initiations, or between an initiation and natural pause. Specific patterns appeared in the conversations and dialogue of students in the physical science laboratory setting in this data and will be discussed in Chapters IV and V. These patterns have also been seen in other studies. Many different concepts have been studied using DA and determined to help support continued and active dialogue among peers. The way students take turns or correct, either themselves or others, can allow for determining what patterns are most useful and effective in building productive conversations in the science classroom. The communicative repertoires used, and the style of talk can also help with this.

Using the transcription methods Jefferson (in Lerner, 2004; see Table 3.4 below) developed and the analysis methods used across DA (Gee, 2014a; 2014b; Jefferson, 1974, 1984, 1985, 1996; Jefferson & Schenkein, 1977; Rymes, 2016; Sacks et al., 1974; Schegloff, 1999; Schegloff & Sacks, 1973; Strauss & Feiz, 2014), it was possible to determine patterns of talk that occur across student-student dialogue in the laboratory environment. All data were considered, and representative samples were chosen to be discussed in the results. All conversations were coded for productive and patterning purposes.

The audio recordings were sent to a transcription service for initial transcription, then each set was edited using the more specific transcription notations mentioned above. After the transcriptions were edited, the finished scripts were uploaded into HyperReseach, to better organize the coding process.

Table 3.4
Transcription Notations by Jefferson

Symbol	Name	Use
[text]	Brackets	Indicates the start and end points of overlapping speech.
=	Equal Sign	Indicates the break and subsequent continuation of a single interrupted utterance.
(# of seconds)	Timed Pause	A number in parentheses indicates the time, in seconds, of a pause in speech.
(.)	Micropause	A brief pause, usually less than 0.2 seconds.
. or ↓	Period or Down Arrow	Indicates falling pitch.
? or ↑	Question Mark or Up Arrow	Indicates rising pitch.
,	Comma	Indicates a temporary rise or fall in intonation.
-	Hyphen	Indicates an abrupt halt or interruption in utterance.
>text<	Greater than / Less than symbols	Indicates that the enclosed speech was delivered more rapidly than usual for the speaker.
<text>	Less than / Greater than symbols	Indicates that the enclosed speech was delivered more slowly than usual for the speaker.
°	Degree symbol	Indicates whisper or reduced volume speech.
ALL CAPS	Capitalized text	Indicates shouted or increased volume speech.
underline	Underlined text	Indicates the speaker is emphasizing or stressing the speech.
:::	Colon(s)	Indicates prolongation of an utterance.
(hhh)		Audible exhalation
(.hhh)	High Dot	Audible inhalation
(text)	Parentheses	Speech which is unclear or in doubt in the transcript.
((italic text))	Double Parentheses	Annotation of non-verbal activity.

Note: Jeffersonian Transcription Notation (Jefferson, 1984) recommends the use of these symbols as indicated above.

Discourse Analysis Process

The building tasks of identities, practices, significance, and relationships suggested by Gee (2014a; 2014b) guided the questioning of the data. For example, the question of significance "how is this piece of language being used to make certain things significant or not and in what ways?" (p.32) was considered as the initial coding progressed. Also, the questions of identity that emerged informed the conclusions about identity and authority that became the theoretical codes later in the process as will be explained. Noting the use of keywords in the transcriptions. They were uploaded to HyperResearch and the word count function was used to tabulate a word count for all words. Reports were then run based on the word list and what would have been considered key to the specific lab. For example, in the Levers 'R Us lab (LRU), some keywords included lever, levers, first class, second class, third class, fulcrum, resistance and so on. This was done to see what percent of words were possibly related to the lab, and to determine if the data would show productive talk since using scientific language is a productive marker (Lemke, 1990). Rymes (2016) explains that context and communicative repertoires are important to DA, therefore looking at the words used provided a chance to see if the communicative repertoires of the students included keywords and science language. Once this was determined, the initial line-by-line coding began.

HyperResearch was a useful tool in organizing the data; it did not, however, play a significant part in the analysis of the data. It just provided a platform to store and code, and it implemented counts of the different codes to get simple percentages that will be shown in Chapter IV.

Unit of Analysis

When dealing with spoken discourse, Cazden (2001) points out that there are several problems encountered in analysis. One is deciding what size pieces the dialogue should be divided into to maximize the amount of information gained in the analysis. Criswell (2009) points out that there is a need to be able to zoom in and out when studying spoken discourse. He

> indicates that relying on a single discourse analytical unit will likely be insufficient…and that what is really required is a system of related units. Further, the way in which those units are related must be clearly specified so that the means for analyzing and describing the movement back and forth between them may be made readily accessible (Criswell, 2009 p. 99).

He suggests that the system of units suggested by Wells (1999) is most useful. In this system, the smallest unit is the *move,* and they are separated by what they accomplish; *initiation* (I), *respons*e (R) or *follow-up* (F). And these *moves* happen within a speaker's *turn*. A *turn* can be composed of multiple *moves,* but these are usually related. From *turns*, Wells combines them into *exchanges*.

In grounded theory studies, line-by-line coding is usually the first step in analysis (Charmaz, 2006). For the current study, the line-by-line was best represented by making *turns* the smallest unit considered and they were coded by what they accomplished, such as a function or action in the conversation. In an open coding, each *turn* was coded with the open codes listed in Table 3.5. The categories these open codes represent in the extant literature are also listed in Table 3.5.

Table 3.5
Open Codes for Discourse Moves

Open Code	Category assigned based on Literature
Opening	Initiation
Answer to previous utterance	Response
Response to a previous utterance (but not the immediately preceding one)	Response
Response introducing uncertainty	Response
Read Aloud	Response
Statement without a clear connection	Response
Positive assessment of previous utterance	Evaluation
Negative assessment of previous utterance	Evaluation
General Feedback	Feedback
Explanation	Feedback
Statement of Uncertainty	Feedback
Thought	Feedback
Extension of previous explanation	Elaboration
Extended feedback	Elaboration
Question	Inquiry
Confirmatory Question	Inquiry
Request for help or information	Inquiry
Suggestion of possible answer	Inquiry
Question from or about the activity	Inquiry
Prompting of following action	Prompt
Joke	Side Comment
Interjection	Side Comment
Positive agreement to previous utterance	Confirmation
Negative agreement to previous utterance	Confirmation

Marking Individual Turns

Each speaker's *turn* was coded by its function or *move* in the conversation and one *turn* could be made of multiple *moves*; however, most were not. The initial coding was done open with the functions making themselves apparent from the data rather than the literature. After initial coding, the open codes were combined in order to make them more succinct, as well as to match the existing literature (e.g.; de los Santos, 2011; Lemke, 1990; Mortimer & Scott, 2003). The definitions of the combined codes from literature can be found in Table 3.6. Due to this combining, some functions or *moves* were determined to be more of a sub-function and are listed as sub-codes below in Table 3.6. The main codes became *Initiation, Response, Feedback, Inquiry, Elaboration, Prompt, Confirmation, or Evaluation*, with most being found in the literature as well (Mortimer & Scott, 2003), though some were more recently added. *Elaboration, Prompt* and *Confirmation* were added by de los Santos in his 2012 study, and *Inquiry* was added in this study. Though the act of questioning was mentioned in other studies, it was not separated and was usually also in the form of an *initiation* (Mortimer & Scott, 2003).

Counts of each function coded were tabulated and percentages calculated to see what the occurrence of each was in comparison to the others and see if patterns emerged. It was possible for a *turn* to be coded twice. For example, if the student provided feedback on a previous topic, then issued an *inquiry* or *prompt* for a next possible action in the same *turn*, multiple *moves* would be represented. It was also possible for one *turn* to be coded as both an *initiation* and another function such as *inquiry*, as asking a question is usually how the conversations studied in classrooms are started, though these studies focused on teacher-student conversation (Lemke, 1990).

Table 3.6
Codes for Discourse Turns

Code	Symbol	Explanation	Example
Initiation	I	The beginning of the interaction, usually in a form of a question or a new direction in the discourse	[I] Connie: What elements appear to be in the same family? Why do you think so?
Response	R	Response to a previous utterance, either in the form of an answer to a question or a response to a previous comment (could be in the form of a statement, introduce uncertainty, or reading from the lab instructions) Sub-codes[x]: Answer to previous utterance, Read-aloud, Statement without a clear connection, Response to a previous utterance (but not the immediately preceding one), Response introducing uncertainty,	[R-answer to previous utterance] Henry: One. That's the, um, potassium chloride.
Evaluation	E	Positive or negative assessment for a response or answer	[E] George: We're supposed to write it down.
Feedback	F	A non-evaluative statement about the previous utterance that may suggest what the next utterance might be Sub-codes[x]: General feedback, explanation, statement of uncertainty, thought	[F-statement of uncertainty] Henry: It's- I guess it's kind of foaming.
Inquiry[*]	Q	A question, could be an ask for more information, question about the lab, a question to introduce uncertainty, or a suggestion of a possible answer Sub-codes[x]: Confirmatory question, Suggestion of Possible Answer, Question from or about the activity, request for help or information	[Q-confirmation] Connie: All of the AG's. Right?
Prompt[+]	P	Feedback that prompts for more details or a better explanation in the next utterance	[P] Brian: Go and do it.
Confirmation[+]	C	Feedback that confirms either positively or negatively the previous utterance	[C] Brian: Yeah, (mumbled speech)
Elaboration[+]	L	Feedback that elaborates on the previous utterance, usually in the form of an example or explanation	[L] Andrew: They're both- they both silver.

Table 3.6 cont.
Codes for Discourse Turns

Code	Symbol	Explanation	Example
Side Comment	SC	A single utterance or short interaction within an on-topic conversation, usually a one-liner joke or an unrelated comment that did not stop the flow of the on-topic interaction	[R-answer to previous utterance, R-read aloud] Brian: This one isn't going to work, it keeps falling off. Okay. Move the match to the 15-centimeter mark. Okay. This thing sucks. [SC] Andrew: I say about the- don't say that about my ruler that I found in the garbage. [SC] Brian: Sure, it was that- it was hidden behind a food wrapper, but still it was… (mumbled speech) [R] Brian: Okay. So, we've got our matches, we've got our pencil, and we got our strings... still...

* Category added in this study, $^{+}$ added to the literature by de los Santos (2011) study, ^{x} sub-codes were marked first then fit into the appropriate category

In the *SC* example, Andrew's comment about his ruler followed the flow of the conversation and drifted the conversation momentarily *off-topic*, however the work continued and though Brian responded, his talk fell off as the conversation returned to *on-topic* discussion. In the overall conversation, the flow was not stopped or sidelined by the joking nature of Andrew's comment about the ruler.

Categorizing Sequences (E*xchanges* or Conversations)

Using the definitions included in Table 3.7, exchanges were broadly identified by *on-topic* or *off-topic* and who the interlocutors were. *On-topic* and solely between students were the exchanges that were further analyzed by function of the coded *moves*.

Table 3.7
Categories for Types of Exchange Interactions

Category	**Explanation or Pattern of Exchanges**
Student-to-Student Productive Talk	Any *on-topic* interactions that have the qualities of productive classroom talk but are solely between students. Could have small, short interludes of *off-topic* comments (*side comments*) but these do not dominate the interaction.
Teacher Help	An interaction with the teacher for any reason, but mostly were for clarification of instructions, none were recorded for pattern of overall interactions
Interruption	A series of utterances that were not related to the lab or any science topic and lasted for more than 3 utterances in a row

Teacher help was any conversation where the teacher was a main interlocutor and were considered to be an on-task and *on-topic* conversation. These conversations were noted but the overall pattern was not coded by *open-chain*, *closed-chain*, or *I-R-E*, due to the desire to study only student to student conversations. Therefore, they were excluded from further analysis. *Interruptions* were full conversations on their own (and not coded for *open-chain*, *closed-chain* or *I-R-E* due to their status as *off-topic*) that were completely and fully *off topic*. *Side comments* were coded within the *on-topic* conversations, and thus were part of the overall conversation's pattern, and were coded as their *function* such as a *response* or *joke* or one of the other sub-codes. They were usually one *move* presented as a *joke* or other *off topic* comment that did not interrupt the flow of conversation or lead the group *off topic*.

The pattern of exchange for the *Student-Student Productive Talk* was determined by looking at what occurred between *I moves*, or obvious starts and stops in the flow of conversation represented by pauses by the students. These codes were the focused codes used in a second round of coding. The conversations were coded as *Open-Chain*, *Closed-Chain*, *I-R-E/I-R-F* (defined in Table 3.6) (Mortimer & Scott, 2003). Other conversations that were *off topic* were coded as *Interruptions*. And though considered *on-topic*, *Teacher Help* was coded separately due to the focus of the study being student to student interactions (defined in Table 3.5) and was not coded by *open-*, *closed- chain or I-R-E/I-R-F*.

Mortimer & Scott (2003) originally defined three discourse patterns commonly found in science classrooms; (1)*I-R-E* or *I-R-F* or *triadic* pattern, (2) *I-R-F-R-E,* or *closed-chain* pattern, and (3) *I-R-F-R-(E)* where the parenthetical E indicates that it is missing at the end of the interaction, so it is an *open-chain* pattern (defined in table 3.8). However, Mortimer and Scott's (2003) reporting were of conversations that were exactly 3 or 5 *moves* and always between teacher and student, whereas in this study, only student-to-student exchanges were coded, and the chain was 5 or more *moves.* Most *open-* and *closed-chains* were significantly more than 5 *moves*.

Table 3.8
Categories for Discourse Exchanges

Category	Explanation or Pattern of Interaction
Open-Chain	I-R-F-R-(E) the parenthetical E indicates that is missing at the end of the interaction, in this study the open-chain pattern was not limited to the four utterances represented in this description, they were overall a conversation that had no final evaluative statement or conclusion
Closed-Chain	I-R-F-R-E with a final E at the end of the interaction, in this study the closed-chain pattern was not limited to the five utterances represented in this description, they were overall a conversation that had a final evaluative statement or conclusion
I-R-E/I-R-F	Initiation-Response-Evaluation or Initiation-Response-Feedback, could have had multiple responses in this due to multiple interlocutors in the two groups of three, but were never longer than four utterances total and usually no longer than a few seconds in overall length.

In this study, when a conversation was marked *I-R-E/I-R-F* there was the possibility of having more than three utterances (which is what is seen in the classic literature on *I-R-E* or *triadic* patterns in the classroom). This is due to the fact that there are more than two interlocutors in some groups, however the overall *triadic* pattern of *moves* remained. For example, student 1 starts with an *I*, then student 2 and 3 both *R* in two separate *turns* or as a chorus, and student 1offers an *E* or gives some kind of *F* and the conversation stops or pauses before picking up again with another *I*. *I-R-E* and *I-R-F* are listed in the literature as a different type of conversation than the longer chain *open*- and *closed-chain*, however they are only studied between two interlocutors, so in the case of three interlocutors, the identified pattern may have had 4 *moves,* but the two middle were responses to the *I,* rather than each other. Both *R* could have been an independent *R* to the *I*. And thus, would have stood alone as a *R* in the conversation if the other party was not there.

Once the conversations were categorized, representative samples of *exchanges* were chosen for the discussion that will be presented in Chapters IV and V. Counts of each category of *exchanges* were tabulated and percentages calculated to see what the occurrence of each was in comparison to the other types of conversation or percentages across groups. This data will be presented in Chapter IV.

Summary

The goal of this chapter was to outline the research method used to answer the research questions. A discussion of the procedure, participants, and data collection outlined the specifics of how the study was conducted. A constructivist grounded theory methodology was used to develop a framework on what students are talking about when they are in self-directed conversation during lab activities and how these conversations can be studied. All study participants contributed to this theory by sharing their experiences and conversations. Chapter IV's goal is to provide the results.

CHAPTER IV: DATA

Introduction

Student verbal conversation, in response to specific lab activities during class, has been seen to demonstrate students' understanding of scientific inquiry, the nature of science and productive conversation (Hofstein, 2015; Hofstein et al., 2005; Hofstein & Lunetta, 1980, 1982, 2004, 2016). The data are drawn from five labs in a 9th-grade physical science laboratory setting (the fifth was recorded but remained unused due to data saturation) to find evidence of patterns in *on-task* and productive conversation. These sources are from four laboratory experiences that were divided into nine sessions. The student conversation is presented as precisely as could be heard in the participant activity. Excerpts include the students' pseudonyms and the teacher's pseudonym. Table 3.2 shows the amount of laboratory time the students experienced by group and laboratory activity (all sessions are included in the times listed; therefore, it is total time recorded on the lab across class periods/sessions). Table 3.3 shows how the nine sessions were divided into the four labs. For example, Group 1 had an hour and thirteen minutes divided across the three sessions of the Levers 'R Us lab.

Types of Exchanges and Frequency of Patterns within Groups

Dialogue exchanges were coded as *on topic*: *Open-Chain, Closed-Chain, I-R-E/I-R-F, Teacher Help*; and *off topic*: *Interruption*. The definitions and examples of these categories are in Table 4.1 below. Each *turn* has the code for it in brackets prior to the speaker's name and transcription of what was said. For example, if [I, P] appears before the speaker's name that means the following was coded as *Initiation* and *Prompt* in the initial turn-by-turn coding of individual utterances. The overall pattern in the conversation is what was determined in the second round of coding where the category was assigned. Therefore, conversations that were categorized as *Open-Chain* had a general format of an *Initiation* to start and some combination of *feedback, prompt, inquiry, response, elaboration, side comment,* or *confirmation* utterances for several *turns* following but no clear evaluative statement before the conversation ended or shifted to other topics, whereas *Closed-Chain* did have a final evaluative statement or a statement with a final intonation.

Once each turn was coded for the types and times of the representative exchanges were analyzed to conclude what the students were achieving or not achieving through their dialogue and identify larger patterns across categories and groups. There were multiple new questions that developed in this process, but to have a coherent narrative for this study, those questions were set aside for later consideration.

Table 4.1
Example Conversations for Categories for Discourse Interactions

Code	**Pattern of Interaction**	**Sample Conversation**	
Open-Chain	I-R-F-R-(E) the parenthetical E indicates that is missing at the end of the interaction	**Conversation 1**	
		[I] Dawn:	Okay, it says click the plus side for each of the boxes (mumbled read-aloud) mass number……Oh?………Oh!...…+
		[Q] Felicia:	Did you figure it out?
		[R-read aloud] Dawn:	To view changes as you change the number of particles in the atom.
		[Q] Felicia:	What plus side do you choose?
		[F-statement of Uncertainty] Dawn:	All of them?
		[F-thought] Felicia:	Oh….
		--	

Table 4.1 cont.
Example Conversations for Categories for Discourse Interactions

Code	Pattern of Interaction	Sample Conversation
		Conversation 2 [I] Connie: What elements appear to be in the same family? Why do you think so? [F-thought] Brian: Uh... [F-explanation] Andrew: Because they both have- [R] Brian: (Groaning) [L] Andrew: They're both-they both silver. [Q-confirmation] Connie: All of the AG's. Right? [F] Brian: Yeah, (mumbled speech) [R] Andrew: It's the silver, it's the sulfide, it's the... Iodide, it's the bromide, it's the chlorodide-chlor-chloroxide. (Sing-song voice) [Q-uncertainty] Connie: What is-what? [F-uncertainty] Andrew: I'm not sure. Should I say, wo- [R-statement, SC] Brian: You guys suck! Just... [R, SC] Andrew: Thank you!
Closed-Chain	I-R-F-R-E with a final E at the end of the interaction	**Conversation 1** [I] Connie: Okay. So we need... [R] Andrew: Atom. [R-read aloud] Connie: Reset back to your original helium atom. [Q-question introducing uncertainty] Brian: Wait. What? [Q] Connie: So don't we need to put in the helium element? [R- read aloud] Brian: Create a helium atom. [F] Andrew: Also, guys I just looked at the worksheet answers. [E] Brian: Okay. [Q] Andrew: Should I have looked at the worksheet answers? [E] Connie: I don't know.

Table 4.1 cont.
Example Conversations for Categories for Discourse Interactions

Code	Pattern of Interaction	Sample Conversation
		Conversation 2 [I] George: And which one is that? [R-answer to previous utterance] Henry: One. That's the, um, potassium chloride. [R-statement] George: So, right now we just mix the potassium chloride with the silver nitrate and it's making a blue-like substance. [F-statement of uncertainty] Henry: It's- I guess it's kind of foaming. [R-statement] George: And now we are stirring it with these tiny little toothpicks. [R-statement] Henry: The broken toothpicks, stud muffin. [R-statement] George: The broken toothpicks. Oh, (explicative). We're supposed to be (mumbled speech) [E] Henry: I did not hear that. [E] George: We're supposed to write it down.
I-R-E	Initiation-Response-Evaluation	**Conversation 1** [I] Connie: Do I see green? Ah. [R] Group: Whoa. [E] Brian: That's greenish-blue. --- **Conversation 2** [I] George: What evidence of a chemical reaction do you see in this lab? [R, E] Henry: Cha[nge of color. [E] George: [Change of color.

Table 4.1 cont.
Example Conversations for Categories for Discourse Interactions

Code	Pattern of Interaction	Sample Conversation
I-R-F	Initiation-Response-Feedback	**Conversation 1** [I] Felicia: Ok so I think is, did you get third? [R] Dawn: (mumbled speech, suggested answer, questioning tone) [F] Felicia: I think it's third? -- **Conversation 2** [I] George: What was the metal ion in the unknown x? How did you know? [R] Henry: How do you know? It produced the same color. [F] George: It's like a reddish orange though?

*one lab required placing a certain number of drops into a chem tray, the counting was coded as a *read-aloud*. [+]Please refer to Appendix 1 for the transcription formatting, as things that are usually grammar related, here are related to tone.

In the *Open-Chain* conversations, notice the fading or trailing off of the conversation. In the case of Conversation 1 in Table 4.1, the group trailed off into a long pause and then picked up a new topic of conversation. When listening to this conversation and the following pause, you can tell they figured out what they needed to move forward, but there was no final evaluative statement rather just the "oh…" followed by a long pause of 30 or so seconds. In the case of conversation 2, the final line of "Thank you!" may sound final, but it was not an evaluation of anything in the core conversation but rather part of the side comment that the conversation trailed into before falling off and picking up with a new topic. Following on from that comment, the group had a couple of *side comments*, then started a fresh conversation on another *on-topic* point.

In the *Closed-Chain* conversations, they have a final closing statement with a period at the end, which means the statement had a final falling pitch. It was clear that the topic was done and they either moved on with another topic or had a pause before conversation began anew. For the *I-R-E* and *I-R-F* examples, you can see and hear a similar pattern. The *I-R-E* had a final falling pitch of a conclusive statement and the *I-R-F* had a more open trailing or rising pitch indicating a questioning or uncertain tone.

As will be discussed in the individual group descriptions later and in Chapter V, the conversations with their cadence and flow are hard to capture in a written transcription. The overall tone of a comment can be questioning but then quickly be followed by a more final sounding statement as in the *open-chain* conversation 2 example. The final "Thank you!" was exclamatory and would have sounded conclusive if heard alone, however the cadence of the previous utterance and the *side comment* nature of the "thank you" did not produce a conclusive comment and showed the way a later comment can change the previous comment's function.

In the first *closed-chain* example, the finality of Brian's *read-aloud* of "Create a helium atom" seems that it should be the close of the exchange, but in the heard cadence and flow Andrew's next comment was clearly part of discussion because Connie's question was being answered by both Brian and Andrew's next comments. This happened often when the group was made of 3 members. A comment that would seem final would be made by one participant and another participant would be responding simultaneously or to the same question and would push the conversation further. So sometimes an *open-chain* conversation had an authoritative "final" sounding comment in the middle of the conversation that was either interrupted by another or was disregarded as the conversation continued to an eventual trailing off to silence or significant pause or another clearer final statement.

In the next two tables (Tables 4.2-4.3), Groups 1 and 2 are compared in various ways. Here, Group 1 remains the most conversive group which, as will be reported in the next set of tables, was not surprising. They simply talked more than Group 2 in the same amount of time, which was audibly heard when listening to the recordings. However, the overall percentage of *on-topic, off-topic,* and *teacher help* follows the overall pattern seen in the table 4.3. The *on-topic* for both groups combined was 60.5%, *off-topic* was 25.8%, and *teacher help* was 13.9%. These two tables represent all the recorded data that was coded for Groups 1 & 2.

Table 4.2
Percentages of Conversations by Type on All 4 Laboratory Experiences

	Closed Chain	**I-R-E**	**Open Chain**	**Interruption**	**Teacher Help**
Group 1	25.3%	6.2%	29.2%	28.0%	11.3%
Group 2	14.4%	11.5%	33.7%	20.2%	20.2%
% total convo (2 groups)	22.2%	7.8%	30.5%	25.8%	13.9%

Table 4.3
Percentage of Group Conversations by On- or Off-topic on 4 Labs (n=361)

	On-topic	***Off-topic***	***Teacher Help***
Group 1	60.7%	28.0%	11.3%
Group 2	59.6%	20.2%	20.2%
Total category	60.5%	25.8%	13.9%

Here in Tables 4.4-4.5, the time represented is solely from the last two labs (FOE and Flames) as they were recorded for all 3 groups which allows the fair comparison of the groups. Here the overall *on-topic* conversation percentage to the *off-topic* percentage is like the patterns in all the previous tables, with *on-topic* at 69%, *off-topic* at 15.5%, and *teacher help* at 15.5%. However, Groups 1 & 3 were more talkative than Group two.

Table 4.4
Percentages of Conversations by Type on FOE and Flames Labs

	Closed Chain	**I-R-E**	**Open Chain**	**Interruption**	**Teacher Help**
Group 1	24.0%	9.6%	38.5%	13.5%	14.4%
Group 2	6.1%	14.3%	42.9%	20.4%	16.3%
Group 3	13.7%	17.8%	37.0%	15.1%	16.4%
% total convo (3 groups)	16.8%	13.3%	38.9%	15.5%	15.5%

Table 4.5
Percentage of Group conversations by On- or Off-topic on FOE and Flames Labs

	On-topic	***Off-topic***	***Teacher Help***
Group 1	72.1%	13.5%	14.4%
Group 2	63.3%	20.4%	16.3%
Group 3	68.5%	15.1%	16.4%
Total category	69.0%	15.5%	15.5%

Group Characteristics and Patterns by Labs

The following tables (4.6 to 4.8) show the counts of conversations as categorized during analysis based on the lab being performed and the percentages of their occurrences either across groups or conversation types as noted.

Table 4.6
Percentage of Conversations (convo) by Type by Lab (actual number of instances)

	Closed Chain	**I-R-E**	**Open Chain**	**Interruption**	**Teacher Help**	**Total Convos of Lab**
LRU (total convos)	13.5% (22)	4.9% (8)	23.3% (38)	41.7% (68)	16.6% (27)	163
Atom (total convo)	66.7% (30)	6.7% (3)	24.4% (11)	2.2% (1)	0.0% (0)	45
FOE (total convo)	16.4% (11)	0.0% (0)	50.7% (54)	16.4% (11)	16.4% (11)	67
Flames (total convo)	17.0% (27)	18.9%(30)	34.0% (54)	15.1% (24)	15.1% (24)	159
% Total category (conversation type total)	20.7% (90)	9.4% (41)	31.6% (137)	24.0% (104)	14.3% (62)	

Table 4.7
Percentage of Conversations by On- or Off-topic by Lab

	On-topic	***Off-topic***	***Teacher Help***
LRU	41.7%	41.7%	16.6%
Atom	97.8%	2.2%	0.0%
FOE	67.1%	16.4%	16.4%
Flames	69.8%	15.1%	15.1%
Total category	61.7%	24.0%	14.3%

In Table 4.6, the percentages of the category of conversation by lab is represented. For example, out of 163 conversations in the Levers 'R' Us (LRU) lab, 13.5% of them were *closed-chain* and 4.9% were *I-R-E*. In the final row, the total percentage of the category from the total of all conversations (n=434) is presented. The only lab that did not follow a similar amount of *on-topic* versus *off-topic* conversation was the LRU lab. The Atom Simulator (Atom) Lab was the most *on-topic* to *off-topic* with 97.8% being *on-topic*, and there was no *teacher help* throughout this lab. Overall, there was a preference toward *open-chain* conversations in all the labs except the Atom lab where *closed-chain* was at a higher percentage. In all except the Flames lab, there was little use of the *I-R*-E conversations. There was a higher percentage of *I-R-E* conversations (18.9%) in the Flames lab than in the other labs.

In Table 4.8 we see that each groups' percentage of conversation types from their total conversations by lab. For example, Group 1 had 13.2% of their 121 conversations that were *Closed-Chain* in the LRU lab. This information is separated out by groups in this table to make for easier referencing as the groups are discussed. Here it is useful to note the percentages across the types of conversation had by each group in the individual labs. This is beneficial because it can be more easily seen how the groups performed in the same lab. It can also be seen that there was an overall preference to *open-chain* conversations in all labs except the Atom lab where *closed-chain* was used more often. It is also interesting to note the higher use of *I-R-E* in the Flames lab sessions in all the groups.

Table 4.8
Group Percentages of Conversation Types for Each Lab Type Analyzed

		Closed Chain	**I-R-E**	**Open Chain**	**Interruption**	**Teacher Help**	**% of lab convos across groups (Total # Convos for group)**
Group 1	**LRU**	13.2%	3.3%	24.0%	47.9%	11.6%	74.2% (121)
	Atom	75.0%	6.3%	18.8%	0.0%	0.0%	71.1% (32)
	FOE	24.1%	0.0%	41.4%	10.3%	24.1%	43.3% (29)
	Flames	24.0%	13.3%	37.3%	14.7%	10.7%	47.2% (75)
Group 2	**LRU**	14.3%	9.5%	21.4%	23.8%	31.0%	25.8% (42)
	Atom	46.2%	7.7%	38.5%	7.7%	0.0%	28.9% (13)
	FOE	10.5%	0.0%	42.1%	21.1%	21.1%	28.4% (19)
	Flames	3.3%	23.3%	40.0%	20.0%	13.3%	18.9% (30)
Group 3	**FOE**	10.5%	0.0%	68.4%	21.1%	0.0%	28.4% (19)
	Flames	14.8%	24.1%	26.0%	13.0%	22.2%	34.0% (54)

Interruption and Conversations with *Side Comments* compared by Group and by Lab

In the next five tables (4.9-4.13), a comparison of number and/or percentage of interruption conversations and conversations with side comments within them are described, first by group breakdowns and second by lab performed. These comparisons are needed to be able to talk about the overall off-topic type behaviors since side comments are by nature off-topic but occur in an overall on-topic conversation. To present this data, all on-topic student-to-student productive talk conversations that had at least one side comment within it were counted. So, the example in Table 3.6 of side comments would have counted as one conversation in the tables below even though there were multiple comments within the conversation. Then that count was compared to the overall total conversations as well as the interruption conversations (the data on interruptions is repeated here for ease of comparison, they are pulled from various tables above).

Table 4.9
Percentage of Group Conversations for Interruptions and Conversations with Side Comments (number of conversations)

	Interruptions	***Convos with Side Comments within***	***Total of all Convos per group***
Group 1	28.0% (72)	11.3% (29)	257
Group 2	22.6% (21)	2.9% (3)	104

Table 4.10
Percentage of Group Conversations for Interruptions and Conversations with Side Comments on FOE and Flames Labs (number of conversations)

	Interruptions	***Convos with Side Comments within***	***Total of all Convos per group***
Group 1	13.5% (14)	11.5% (12)	104
Group 2	20.4% (10)	4.1% (2)	49
Group 3	15.1% (11)	11.0% (8)	73
Total category	15.5%	15.5%	226

Table 4.11
Percentage of Group Conversations for Interruptions and Conversations with Side Comments on All Labs (number of conversations)

	Interruptions	***Convos with Side Comments within***	***Total of all Convos per group***
Group 1	28.0% (72)	11.3% (29)	257
Group 2	20.2% (21)	2.9% (3)	104
Group 3	15.1% (11)	11.0% (8)	73

Table 4.12
Percentage of Conversations for Interruptions and Conversations with Side Comments by Lab (number of conversations)

	Interruptions	***Convos with Side Comments within***	***Total of all Convos per group***
LRU	41.7% (68)	13.3% (12)	163
Atom	2.2% (1)	11.3% (6)	45
FOE	16.4% (11)	6.0% (4)	67
Flames	15.1% (24)	6.7% (18)	159
Total category	24.0% (104)	9.2% (40)	443

Table 4.13
Group's Percent of Conversations by Type by Lab (number of conversations)

		Interruptions	*Convos with Side Comments within*	*Total of all Convos per group*
	LRU	47.9% (58)	9.1% (11)	121
	Atom	0.0% (0)	19.0% (6)	32
Group 1	**FOE**	10.3% (3)	10.3% (3)	29
	Flames	14.7% (11)	12.0% (9)	75
	LRU	23.8% (10)	2.4% (1)	42
	Atom	7.7% (1)	0.0% (0)	13
Group 2	**FOE**	21.1% (4)	5.3% (1)	19
	Flames	20.0% (6)	3.3% (1)	30
Group 3	**FOE**	21.1% (4)	0.0% (0)	19
	Flames	13.0% (7)	14.8% (8)	54

Group 1: Andrew, Brian and Connie

This group was an interesting mix of *on-topic* and *off-topic* talk. Members were generally chatty in the cadence of conversation which would feed the chaos theory of *off-topic* talk. However, they spent the majority of time *on-topic*, they did have several *interruptions*. When looking at the occurrence of conversations with *side comment* code(s) within, Group 1 had more of these than the other two groups. This means part of their *off-topic* talk happened in short bursts within the *on-topic* conversations rather than longer periods of *off-topic* talk, classified as *interruptions*. Andrew had a habit of cracking a joke or one-liner as the conversation went forward. Sometimes Brian and Connie would respond with a laugh or a comment that would extend the *side comment*, but most of the time they simply kept going and just expected Andrew to catch up or get back *on-topic*. However, when they found it distracting, they would stop the flow of the conversation to get Andrew to stop the jokes and move forward.

Conversation Types and Patterns of Interactions

Group 1's overall *on-topic* versus *off-topic* percentages were comparable to the overall averages across labs, and across groups. However, they did have more overall conversations than the other two groups, with 257 noted conversations (59.2%) out of 434 total conversations across the four labs and 104 (46.0%) of the 226 conversations across the Families of Elements and Flames labs. While they had more actual encounters with the teacher, they had the lowest percentage of conversations with the teacher out of their total conversations than the other two groups. But they had about the same amount of interruptive conversation as well (28.0% of 257). They had a slight preference towards *open-chain* (29.2%) to *closed-chain* (25.3%), and similar to all the groups showed a distinct lack of the simpler *I-R-E/I-R-F* pattern (6.2%).

Patterns of Conversations across Laboratory Contexts

The Atom Simulation lab was the only computer simulation done out of the four labs and it was interesting that Group 1 had no *teacher help* conversations during this lab and more *closed-chain* conversations than in the other labs. In the hands-on labs, there was a tendency towards *open-chain* interactions over *closed-chain* and very few *I-R-E* instances. For this group, it was seen that the instances of *interruptions* versus *side comment* conversations mostly varied by lab, but the overall *off-topic* conversations were similar, except the LRU lab that had a higher percentage of *off-topic* than *on-topic* conversations. For the Atom Lab, there were no *interruptions,* and fewer *side comment* conversations than *interruptions* in the Flames lab and were equal on the Families of Elements lab.

Group 2: Dawn, Erin and Felicia

This was the least talkative group. They would have long periods of "silence" (where only background noise could be heard on the recording) and even longer than normal pauses in the flow of conversations. This could be explained by several factors that cannot be ascertained by only an audio recording. The participants could have been gesturing or exchanging words in other fashions rather than spoken. Or as it seems from the recording, they were working and only speaking to confirm or clarify what they were doing individually.

While this group did have a similar percentage of *interruptions* as Groups 1 and 3, they did not have the chatty cadence. As mentioned, when comparing the groups across the 2 labs in which all three participated, the occasion of *interruptions* and *I-R-E* conversations were not significantly different across the groups. But this group had the most silent time within the sessions across the three groups. They had multiple spans of 5 minutes or more between conversations or even single line comments (which were coded by function but not necessarily counted as a *conversation* because the one line stood alone).

Conversation Types and Patterns of Interactions

Group 2 also showed preference toward *open-chain* interactions (33.7%) in their *on-topic* conversations. However, there were more occurrences of *off-topic interruptions* than *side comment* containing conversations when looking at the *off-topic* portion of their talk. Group 2 was much more likely to have entire *off-topic* sections of talk within the time recorded rather than the chattier sounding *side comment* interjections of Groups 1 and 3. In the LRU lab, they had a much larger percentage of *teacher help* (31.0%) than in other labs, and more than in other groups. Their Flames lab did not follow the overall pattern seen everywhere else with a much stronger preference to *I-R-E* interactions, than in all other labs, though the other groups also had a higher percentage of *I-R-E* conversations in the Flames lab, as was noted above.

Patterns of Conversations across context

In all the hands-on labs, the girls were more likely to have *open-chain* interactions within the *on-topic* talk. And they had a much heavier preference to *closed chain* in the Atom lab which was a computer simulation. They had a higher amount than the other groups of *teacher help* in the first lab, but, like Group 1, had none during the Atom lab. They also had only one *side comment* conversation in each lab except in the Atom lab, where they had none.

Group 3: George and Henry

These two boys were similar to Group 1 with respect to general talkativeness. When listening to the recordings, the timing and cadence of George and Henry were like Group 1, in that it was chatty but still *on topic* the majority of the time. They had more *side comment* conversations in the Flames lab in that they included short comments or one-liners that were in a joking manner rather than full *interruptions*. So, while they were having *off topic* thoughts, they were generally good at redirecting themselves without outside (i.e., teacher) prompting.

Conversation Types and Patterns of Interactions

Since there was less data than the other two groups, Group 3's data served as a test to see if patterns continued through a new group, which they did. George and Henry showed an overall preference for *open-chain* conversation (68.4% in FOE, 26.0% in Flames), no *I-R-E* in the first lab and a similar to the other groups spike in *I-R-E* in the final lab, which since there were only two students in this group, the shorter conversations may be more expected. They were generally *on-topic* versus *off-topic.* In their *off-topic* conversations they tended toward *interruptions* over *side comment* conversations. However, they did maintain the chatty nature of talk and generally did not have long periods of *interruptions*, but they were longer than just a line or two so did not qualify as a *side comment.*

Patterns of Conversations across Lab Contexts

The computer simulation was not recorded for this group, due to their late entrance into the study. However, they did vary in their talk across the two labs in which they were recorded, and those nuances will be discussed in chapter V.

Issues of Validity and Reliability

The validity of the chosen method of discourse analysis is high since it is a well-established model. The validity of the study was improved by the multiple coding sessions (initial, focused, theoretical phases) that were set over multiple weeks of interactions with the data. Gee (2014a) explains that validity is constituted by four elements: convergence, agreement, coverage, and linguistic detail. He gives 42 questions throughout his book that lead to a more valid study. He admits it is not possible to analyze every piece of data with all the questions. He also acknowledges that a researcher cannot seek "all possible questions, seek all possible sources of agreement, cover all the data conceivably related to the data under analysis, or seek to deal with every possibly relevant linguistic detail" (p. 143) However, if a study uses multiple building tasks rather than just one and several linguistic details support any conclusions, then a study can be considered valid. . In this study, multiple building tasks of identities, practices, significance and relationships were considered throughout the data analysis process, leading to convergence and linguistic detail, so it can be valid.

However, reliability is limited due to the nature of the study, having only one researcher, and few participants, which does not allow for large generalizations to be made. However, I coded some transcripts twice over a period of time to try to replicate the coding scheme. The database that was developed is limited to the audio files, transcripts, and copies of the lab paperwork, but it does not include visual recordings or the participants' actual completed lab paperwork. There is no guarantee that all student conversations will happen in the same manner as the ones studied, due to the individuality of the participants.

This chapter contains the results of the analysis of conversations and utterances. It also connects the analysis back to the research questions through providing data about the patterns and the changes across context. It demonstrates use of grounded theory methodology in the analysis. The nuances of the data will be explored in Chapter V, but here it is shown that there were similar patterns across the labs and the groups that allow them to be compared in the following chapter.

CHAPTER V: CONCLUSIONS

Introduction

The purpose of this study was to identify what patterns of discourse occur in student-to-student discussion in a physical science laboratory setting when students are engaged in laboratory activities. This leads to a theory for future study and to identify possible patterns across different contexts of the classroom. This chapter includes a discussion of major findings as related to the literature on markers of productive conversation and the definition presented of Student-to-Student Productive Talk (SSPT), communicative approaches and the types of approaches found in this study. This includes issues of identity and authority as related to SSPT, and what qualities of labs may encourage student participation and the occurrence of productive talk. The chapter concludes with a discussion of the limitations of the study, areas for future research, and a summary. The research questions that guided this study are:

1. What are the patterns of talk in student-to-student discourse in laboratory activities in a 9th-grade physical science laboratory setting?
2. Is there any relationship between the patterns of talk and the nature of the laboratory activity?

The framework for patterns of SSPT in the science classroom is informed by findings related to RQ1 and RQ2 which are supported by the current data: (1) The conversations showed specific patterns as well as qualities of SSPT; and (2) The patterns across labs gives clues as to how to encourage SSPT in lab activities. These answers combine to form a possible course of action for the improvement of science classrooms that encourage productive talk by their students. In the development of the study and in the grounded theory method, some other possibilities showed for possible future work. It was seen that student-to-student conversations during science labs may include *identity work,* as defined by Barton and colleagues (2013), and that issues of identity and authority could encourage and support SSPT conversation.

Conclusions related to RQ1: Conversations showed specific patterns and qualities of SSPT

One consideration the literature does not make clear, but may be assumed, is that productive conversation is *on-topic*, however there is no clear definitional references in the literature studied here that indicates that claim in general, except for studies in specific subject areas where it seems that the topic would be the subject itself, though it is not necessarily specified. However, in following the definition for SSPT presented in Chapter II, the focus will remain on the *on-topic* portions of conversations recorded. It is interesting to note, however, that some of the *off-topic* conversations fit the *productive* and student-to-student categories but were just *off-topic* in terms of being science-related. These *off-topic* conversations had several of the markers of *productive* conversations. For example, some *interruptive* conversations had evidence-based argumentation (just not on a science topic), as well as, building on previous utterances, generalizations, and productive resolution, but the topic of conversation was non-academic.

Table 5.1 includes the list of *productive* markers discussed in Chapter II along with the definition of SSPT. There was no clear consensus within the studied literature that proclaimed that *productive* conversations had to have a certain number of markers present to qualify. As stated previously, the conversations studied here were based on the SSPT definition, therefore the talk was *on-topic* and was considered *productive* if it had at least 3 or more of the listed markers. Once these were considered, it revealed all *on-topic* conversations, other than *teacher help,* qualified as SSPT. Interestingly though, *productive* markers were seen in *off-topic* conversations as well, it seems that productivity with language is not found only in academic talk.

Table 5.1
A Summary of Research-based Student-to-Student Productive Talk Definition and Markers

SSPT is any *on-topic* interactions that have three or more of the qualities of productive classroom talk listed below but solely between students. SSPT could have small, short interludes of *off-topic* comments (*side comments*) but these do not dominate the interaction. • Multiple Points of View • Evidence-based discussion and/or argumentation • Effective questioning • Building on previous utterances or "visible" thinking • More non-evaluative feedback than evaluative • Cognitive conflict or decentering • Productive resolution • Co-construction of knowledge Additional Components that were in single sources • Activation of prior knowledge • Generalizations • Communicative struggles • Accountability • And in science, literate use of the language of science

The markers that were present varied in each conversation, but at least three were represented in all of the conversations, but only the conversations between students which were *on-topic* and thus defined as SSPT were analyzed closely in this report. Once the conversation was identified as SSPT, then the pattern of the conversation was decided. The data included in Chapter IV demonstrate that *teacher help* was considered *on-topic* but not closely analyzed since it was not student-to-student only. The only type of conversation considered *off-topic* ended up being *interruptions*. But comparing the number of conversations that had *side comment* moves in them with the *interruption* data was interesting and will be discussed below.

Table 4.11 shows that Groups 1 and 3 were relatively the same with *interruptions* (G1: 28.0%; G3: 15.1%) and *conversations including side comments* (G1: 11.3%; G2: 11.0%), but Group 2 clearly had more conversations that were totally *off-topic* talk (20.2%) rather than interspersing *side comments* (2.9%). This was fairly apparent when listening to the recordings as Groups 1 and 3 had a clear banter and playful cadence, and Group 2 was either on task or engaged in seemingly irrelevant conversation.

Characteristics of SSPT and What Teachers Should Watch for in Their Classes

Evidenced in the data in Chapter IV and using the *productive markers* and definition of SSPT in Table 5.1, the overall *on-topic* conversations found in all groups and across most labs tended to be slightly more *open-chain* or lacking in evaluative statements before the conversation ended. Or, if an *evaluation* statement was made, the conversation may not have ended, because there was a response that continued the conversation. For example, in Conversation 5 in Appendix 2 Table B, Connie in line 13 makes a very final sounding comment of "Our mass is four." Yet, the conversation continues on without pause as Andrew in line 14 does not accept the final statement and continues the conversation onward for several more lines until Andrew calls "done" in line 20. The *evaluative*-attempted response was not accepted as an authoritative claim or was not understood to be an authoritative claim and thus the conversation continued.

When looking at the conversations, the students stayed on the interactive end the majority, if not all, of the time, meaning that almost all the conversations were an exchange between at least two *voices* (remember a *voice* is not a physical one but a representation of a specific point of view) that had an even-footing, rather than one *voice* dominating the conversation or taking a more authoritative stance or single point of view. There were, however, some statements in the student-to-student talk that were treated as non-interactive, such as in the

Families of Elements lab when the students were counting the drops of the chemicals into the chem plates. They generally did not interact during the counting. They either counted together in one *voice* or only one counted (if they even counted out loud). Of course, there were moments when a student tried to interact with the counting student, but they were usually disregarded until the task was done.

Overall, all the conversations, whether *on-topic* or *off*, remained toward the interactive end of the spectrum of the Mortimer and Scott's four classes of communicative approach (2003). When the students were reading aloud to one another or one student took a strong stance, the interactive aspect of the conversation was more limited. In the second situation where a student took a strong stance, the other students would occasionally concede without further conversation. These were still considered productive because the strong stance was built up from the previous conversation or the student was claiming authority in the moment (which will be discussed later).

This interactive tone meant almost all conversations met the "visible thinking" or "building on previous utterances" since the students were clearly understanding the conversation and continuing it or accepting appropriate comments as *feedback* before responding accordingly. The "visible thinking" was the results of the way students talked through problems and guided themselves to solutions. It was also evident that the students were "co-constructing knowledge." Bruner (1987) said that he had come to realize that "most learning in most settings is a communal activity, a sharing of the culture. It is not just that the child must make his knowledge his own, but that he must make it his own in a community of those who share his sense of belonging to a culture" (p. 127). Part of the school culture is the success of achieving learning goals as assessed by the teacher. Since all groups were successful in achieving the learning goals of the labs which was confirmed by Ms. Jones after assessments were given, as well as the clear comradery of the students, it is clear they were able to achieve co-construction of knowledge. A pattern of productive, interactive conversation was, therefore, established.

Since an interactive pattern was seen, it was logical to see the more specific patterns of individual conversations emerge. The common classroom format of *I-R-E/I-R-F* were seen but were not as prominent as the longer *open-* and *closed-chain* conversations. While all other conversations categorized as *open-chain* or *closed-chain* did not follow the exact pattern of *I-R-F-R-(E)* or *I-R-F-R-E*, they did follow the overall concept of either being open-ended and lacking evaluation or closed with an authoritative evaluation before a pause or change in topic. The exact order of the flow of the conversation did not follow the chain related in the literature (*I-R-F-R-E*) because there were times when there were two *responses* before some *feedback* or *evaluation* (so the pattern may have been *I-R-R-F-R*, etc.). For example, in Conversation 7 in Appendix 2 Table B, lines 53-55, Brian instructs to “click on the plus sign” and both Connie and Andrew respond in two different ways but both indicating that it was not possible to do as Brian said.

When dealing with 3 students in one conversation, they could talk over each other when responding to the previous utterance. There also could appear to have multiple *feedback* or *prompting* statements for the same reason. It was interesting to observe how the students negotiated the next response. Did they treat one of the previous pieces of *feedback* as an answer and thus move on to other conversation? Or did they ignore it or question it and continue the conversation forward?

A teacher who wants more assurance that students are engaging in SSPT needs to consider a few things. First, they should not judge the conversations of the students based on a brief pass, they should consider being as inconspicuous as possible and listening carefully to the flow of the conversation. They should try to remain apart from the conversation because their presence may cause the students to begin editing their thoughts because the teacher is listening. Teachers should also consider building a classroom environment where it is acceptable to take educational risks and to be "wrong" sometimes. An environment where the students are encouraged to talk through things with others will help encourage SSPT when they are placed into groups to work on a lab or project. Having the ability to take safe risk is also part of the patterns that show up in the design of the labs as well.

Conclusions related to RQ2: The conversation patterns across lab types provide clues as to how to encourage SSPT in lab activities

As shown in Chapter IV, the data revealed the groups, in almost all cases, stayed *on-topic* most of the time, and were *off-topic* for about a quarter of the recorded conversations. However, when looking more closely at the types of conversations as well as the traits of the individual labs, patterns of overall interactions emerge. These patterns may lend support in deciding what characteristics of different labs support the conversations more appropriately and lead to more productive talk in science classrooms. The four labs examined in this study involved students in different ways including 1) building components to analyze, 2) testing chemicals for their identity, and 3) engaging in a computer simulation that modeled the atoms of certain elements. Interestingly, this led to some differences in the conversations across the labs.

Group 2 is interesting because in the fewer conversations they had, they still were *on-topic* most of the time and were equally or more successful in the assessments (as reported by Ms. Jones) across the labs. They did show a slightly higher tendency to ask for help from the teacher across all the hands-on labs, where the other groups had slightly less tendency to do so. However, Group 2 showed similar tendencies toward *open-chain*, *closed-chain*, and *I-R-E* patterns across the labs as did the other groups. They spiked in *I-R-E* in the Flames lab just like

Groups 1 & 3. They also utilized *closed chain* conversation s more in the Atom lab (46.2% of conversations), just as Group 1 did (75% of all conversations). So even though they talked less, they still confirmed patterns found overall in the study.

Groups 1 and 3 were more chatty, which on initial listening pointed toward the idea of “chaos” or “idle chatter” noted in earlier (Alexander, 2020). However, when listened to more closely, the patterns of *side comments* became clear. To the casual listener or teacher passing by at just the right time, the groups would have seemed to be *off topic*, but they were not. They were simply injecting commentary as they worked. For example, in the *side comment* example in Table 3.6, it would seem to a passerby that the conversation had drifted off topic in the brief discussion of finding things in the garbage, however when listening to the entire conversation it is only a brief aside. Also, in Conversation 4 in Appendix 2 Table A, lines 53-56 when Brian suggests “negative zero” as an answer and Connie responds in line 56 that “Third and negative zero are the same,” someone not privy to the entire conversation might think the students do not understand something, when it is actually a short joke, that allows for Connie and Brian to build a bit of rapport together.

All the groups also showed the ability to work without direct guidance from the teacher since the majority of their conversations were *on-topic*. Barnes (1976) makes the case for allowing friends to work together in the dialogic classroom as students are more likely to be comfortable and vulnerable with friends, thus able to have less editing to their speech, which he thinks could help encourage better co-construction of knowledge. The students in this study had worked together before and the size of the school meant they knew each other fairly well. Ms. Jones’ informed me that they had all worked together at some point in the past so this could have played a part in the patterns I saw. And as the example above from the “negative zero” conversation, the students did work well together, sharing jokes or comments that built rapport.

When looking at patterns across labs, it did not seem to make a difference if the lab was commercial or the product of teacher creation. The groups all had *teacher help* in some places and not in others. Though it was notable that neither group needed *teacher help* during the Atom simulation lab, their conversations nonetheless had many occurrences of inquiries for each other and in positions other than *initiations,* similar to how a teacher might ask questions to further the conversation. In that lab there was also a tendency towards *closed-chain* conversations, which means they were asking questions yet coming to their own conclusive, authoritative answers. This could possibly be explained because they were using a computer simulation, since there was little to no risk in “figuring it out” on their own. In Conversation 5 in Appendix 2 Table B, Andrew, Connie, and Brian are clearly following directions, yet just trying things out. In line 6, Andrew suggests to just “add everything in” and see what happens. This occurs in an example of a *closed-chain* conversation, suggesting that the students may have been more willing to claim assurance when there was less risk of being “wrong.” If they missed something or did something incorrectly, they could just reset the simulation and try again. There was also a bit more “let’s just figure it out” in the Levers ‘R’ Us lab, this was probably from the fact that the worst thing that could happen is the breaking of a ruler or pencil, which are much less risky than chemicals being misused. It was also interesting that the overall interruptions in the Atom Lab were significantly lower, to almost non-existent (2.2% of all Atom Lab conversations), but the side comments were higher at 11.3% of all Atom lab Conversations. This would seem that the flow of conversation was more continuous and the students less distracted than in the hands-on labs.

This “let’s see what happens” approach would not have worked as well in the chemistry labs (FOE and Flames), for hopefully obvious reasons. Of course, Ms. Jones used safe practices and explicitly taught lab safety, however it is cognitively different when a student is working with something that has been represented as possibly dangerous throughout their lives. But interestingly, in the hands-on chemistry labs (Families of Elements and Flames), there was a distinct tendency towards the more open, questioning, and exploratory *open-chain* conversations. Therefore, even though they could not just “figure it out” by trying and re-trying, they did show a more even level of authority and identity amongst themselves yet less assurance of “correctness”, which was apparent by the more open format of conversation.

In the Flames lab, there was a distinct rise in *I-R-E* conversations in all three groups. In this lab, samples of certain compounds were burned to identify trends and an unknown chemical based on the color of the flames produced. This could be the source of the higher incidents of *I-R-E* because the general conversations had an *initiation*, a *response* of the color one person saw, and then a *confirmation* or *evaluation* of the color by another student. This is seen in both examples in Appendix 2 Table C. However, the Families of Elements lab had a similar task in identifying which mixture was the cloudiest yet did not have any actual *I-R-E* conversations. In this case, each student produced a *response* and then a discussion would follow over several turns of *feedback* on the suggested answer. Here however the results could be observed for much longer than the brief flame in the Flames lab, so there could be more discussion over the results. This can be seen in Conversation 3 in Appendix 2, where the group was discussing which ratio had the higher amount of participate. In the Flames lab, the decision had to be made quickly since the chemical only flamed for a moment and the students had a limited amount of chemical.

While more study is needed to make firm conclusions, this study demonstrates that in this class with these students, they were engaged in SSPT through a large portion of all the types of labs. This is important because it has been shown that productive conversations in the classroom result in positive outcomes like co-construction of knowledge and better *identity work* for students to improve their science identity. And since SSPT is built on the basis of *productive talk,* it would be reasonable to conclude it could encourage the same outcomes. The students seemed to be more independent in the computer simulation and require more teacher guidance in the hands-on labs. Group 2 talked much less overall and needed *teacher help* a little more than Group 1 in all four labs (Table 4.3), which could be related to their own identities in science as girls which has been studied in many studies (e.g., Barton et al., 2013; Brickhouse et al., 2000; Carlone, 2004; Farland-Smith, 2009; Hughes et al., 2021). And in Groups 1 & 3, their overall demeanor was chatty which could add to the "idle chatter" conclusion, but they were on-topic even though they did not necessarily sound like they were *on-topic*.

All of this points to having labs that allow more exploration with less risk of an actual dangerous situation, or even possibly better, less risk of "losing face" to fellow students. Labs like this and a classroom environment that makes these discussions and the "just figure it out" philosophy available to students could improve the experiences of students and help build their *social language* and *communicative repertoires* in science. Having safe exploratory labs allows for student to experiment not just with the lab experience but also with their language. It gives them a chance to try on the identity of a scientist which should allow them to see themselves as consumers and doers of science.

Implications and Future Research

Multiple small sample studies provide a platform for future studies and provide a solid framework from which to work. There are many variables to consider in this study that were not or could not have been controlled; this is part of the nature of educational studies. In the current study, the issues of identity and authority showed up like in the de los Santos study (2011) and provided insight into possible future study as well as part of the developing grounded theory being built.

Identity and authority encourage and support SSPT conversations

Of the two continua in the Mortimer and Scott (2003) Framework, the dialogic-authoritative scale is still in play even though the conversations were mostly interactive rather than non-interactive as discussed in the answer to RQ1. Similarly, there are dialogic/non-interactive conversations (though that seems counter intuitive). Then interactive/authoritative interactions can occur, as well, as noted above. In this type of talk, there are interactions between multiple interlocutors but there is only one point of view represented. In other words, there is one *voice* being used by all participants. And if that *voice* is not the students' voice, then the authority is attributed to whomever the *voice* belongs, such as the *voice* of science.

While coding, I observed that some conversations could have been more of a *closed-chain* rather than *open*, but the students seemed to leave the possibility of a different answer open rather than authoritatively state a final evaluative statement, as you might find in a teacher-student interaction. For example in *Open-Chain* Conversation 1 in Table 4.1, Dawn could have spoken with more authority and assurance with her "all of them," however the questioning tone led to an open-ended conversation in the end.

There were also times where a student would offer a possible answer in a *feedback* or *response* and it would be taken by the other students as the answer and move on. This can be seen in Conversation 3 in Appendix 2 Table A (lines 43-44) where Brian suggests an answer and Connie claims it as her own. Here she was not really respecting Brian's knowledge but was taking authority away from him by the forceful nature of her response. Andrew can be seen trying to calm the situation with his comment about not getting mad. This led to the consideration of Identity and Authority and their place in authoritative and dialogic conversations between students.

As discussed in the response to RQ1, the student-to-student conversations remained generally interactive, which may explain the higher amount of *open*- and *closed-chain* patterns over the less interactive *I-R-E* pattern. However, even though *closed-chain* patterns require some acknowledgement of authority in the final evaluative statement, does that authority come from the student or an outside authority such as the *voice* of science? Is it possible for students to assume an authoritative stance and *voice*, and have the identity to connect with each other in an authentic way? Or does overall *identity work* differ when a student takes on an authoritative *voice*? Also to consider, does invoking "the *voice* of science" allow for more claim to the science identity as the student is using the outside authority of science? Can authority be shared with the *voice* of science or with other students? Here is where the ideas of identity and authority discussed in Chapter II appear needed.

Identity, Authority, and Their Roles in Productive Talk. Identity and authority both have a place in SSPT. They encourage students to embody the role of a scientist which may help them better their scientific literacy and improve their appropriation of science overall. These concepts are a part of the student's identity work as defined by Barton and colleagues (2013).

> Who one is and who one desires to be at any given moment is always under negotiation and is contingent upon the resources one has access to and the social, cultural, and historical context in which one seeks to author oneself with and against the expectations of others…Because identities are always in the making and are always socially negotiated, they are impossible to isolate or to name, raising questions about how to study them (Barton et al., 2013, p. 38).

In their work, Barton and colleagues say they have found it "productive to focus on identity work rather than identities" (Barton et al., 2013, p.38). When these scholars define *identity work* they refer to the actions that individuals take and the relationships they form constrained by the culturally, historically, and socially legitimized rules, expectations, and norms that build the spaces in which such work takes place. Each person authors their possible identities through this *identity work* with and against these norms of the worlds in which they live. "There is always dialectical tension between the work that individuals do and how that work is taken up by others over time and space" (Barton et al., 2013, p.38).

Productive markers like activation of prior knowledge, generalizations, communicative struggles, accountability and the literate use of the language of science (table 5.1 identified in single sources) were all seen in the conversations where *identity work* and authority are being constructed and negotiated by the students. Confirming the findings of the de los Santos (2012) study, the identification of the roles of identity and authority were also recognized after the analysis began. While the productive markers were identified in an early stage of data analysis, when the conversations were reanalyzed for identity and authority, it became clear that the markers of productive talk where present. The de los Santos study looked at the verbal interactions of two pairs of students, one pair was Redesignated Fluent-English-Proficient and the other was native speakers of English. As the interactions were coded de los Santos also found a dominant pattern of *open-chain* interactions, with secondary patterns of *I-R-E* and *closed-chain*. The study linked the *open-chain* interactions to a more balanced and shared authority amongst the students and found that the *I-R-E* and *closed-chain* patterns tended to have one student asserting more authority through an identity of being a stronger chemistry student compared to their partner.

This pattern was also evidenced in the current data. Though sometimes, two students would share the authority over the third, which could not have happened in the prior study because the study was of pairs of students. The students experienced more open conversations with somewhat of a more equal footing, or at times an equal un-surety in the answers. The equal footing and shared authority can be seen in the example conversation number 6 in Appendix 2 Table B. In the conversation, Andrew, Brian, and Connie are strategizing on how to build their lever in the LRU lab. In the last lines (33-38) it is clear that students are all in equal authority in deciding how to proceed. And in lines 34-36, each student agrees to the use of four washers, though Andrew suggesting not using all of them, to which Brian says use four, and Connie agrees. When listening to this exchange the tone of all three participants is even and confident rather than sounding resigned or agreeing without thought or desire to agree. This conversation was classified as a *closed-chain* since the conversation ends on the concluding statement that they have the correct number of washers to continue. After the final line there was silence from the participants for a short break before the conversation resumed and the group moved on to the next steps. In this case, all three carried the balanced authority to move forward together, and with equal footing amongst all.

As mentioned in Chapter IV sometimes an *open-chain* conversation had an authoritative "final" sounding comment in the middle of the conversation that was either interrupted by another or was disregarded as the conversation continued to an eventual lapsing into silence or significant pause. This could be an issue of identity and authority within the group. The student making the authoritative “final” sounding comment in the middle of a conversation may show a lack of confidence in their identity and/or authority with the other students, such as feeling like a “weaker” science student. Or it could also be a result of having more than two participants and an inability of the students to give attention to all speakers at one time. This also could possibly be seen in the identity of a “class clown” where they could lack an authoritative tone, or lead to the other students disregarding them, which was sometimes seen around occurrences of *side comments,* as other students might think they were continuing the joke rather than offering an answer. The idea of being the clown and having authority questioned or dismissed can be heard in the *closed-chain* conversation 1 from Table 4.1. When Andrew, who embodied a clownish persona, mentions he has looked at the answer sheet, the others basically dismiss him with a “whatever” tone when saying “okay.”

The result of Brian’s *identity work,* on the other hand, and the way his partners, Andrew and Connie, assumed and agreed to the *identity* he took as a leader of the group. In Conversation 1 in Appendix 2 Table A, this can be seen in the final exchange between Andrew and Brian, Brian opens in lines 11-13, with an explanation of what they should be looking for and how it is different on the periodic table. Andrew answers with “all right” in a questioning manner and Brian promises to explain (signaling a strong belief in his explanation). Andrew then seemingly figures something out and signals this with the declaration of “iodide” and then they repeat “iodide” back and forth with Andrew finally asking in a disbelieving tone in line 24 “you found iodide?” Andrew was seen as the clown of this group and he was usually the one cracking a joke in a *side comment,* so Andrew’s disbelief was feigned in his clownish way. In all the labs up to this point, Andrew had been gleefully accepting his role as the clown in the group, so this question was part of his *identity work* during the previous time with his group.

With identity work, the students who use the aspects of SSPT and/or productive talk in general, can build a stronger identity in the science classroom as well as in science in general. If teachers are able to promote SSPT in their classrooms, they assist their students with building a stronger identity as science consumers, at least, and scientists, at best. Warren et al. (2001) also found that when students were on equal footing and encouraged to bring their full identities including their first language and personal experiences, they tended toward more egalitarian talk. Though this study did not look at the specifics in the same way as this study and the de los Santos studies, it did seem that the active development of accepting the students' own language and experiences were able to set a context where "the students and teachers were able to draw on their familiar, everyday ways of characterizing, organizing, theorizing, and arguing about the phenomena of the natural world" (Warren et al., 2001, p.535) which "allowed them to joke and tease on the one hand, and probe meanings and imagine change in insects and in people on the other" (p. 537). In this Warren et al. did "not see these everyday ways of talking and theorizing as in opposition to scientific ways, or even as fully distinct from them" (p.537) but it did allow the students to build an identity and some authority in the subject.

Wallace (2004) addresses the need for further "long term, in-depth studies of students' gradual appropriation of academic science language" (p. 912). She asks "under what conditions do students most readily appropriate scientific language? Are experiences doing science the only necessary factor for such appropriation? How do reading and writing practices influence the appropriation? Do students see value in the appropriation?" (Wallace, 2004, p. 912). The current study considered these questions and others as the data was analyzed. From that consideration, I think therefore, one possible course to answering some of them is looking at student to student talk, their use of vernacular and scientific language, and their embodiment of the identity and authority to exist in the *figured world* of science. This provides a possible avenue to study further in this data set and may give more hints to the *identity work* being done in the classroom. Lee (2012) explains "Language, as preeminent social practice, is inseparable from identity. We use talk to do things and bring all manner of objects, including ourselves and others, into being" (p. 38). Lee (2012) also pointed out that

> Starting from our current troubled (and troubling) spaces called classrooms, where we literally coerce youth to occupy, identity-based research can help us to transform them into places that youth want to inhabit for the long term and in which they invest their talents in science (Lee, 2012, p. 42).

Following that logic, further discourse analysis of student-to-student conversation may prove useful in building the classrooms that students will want to inhabit. This desire should occur because of the allowance to develop their identities as scientists, to build their authority in the subject, and build authentic relationships with each other and the subject of science.

Considerations for Future Investigations

Further analysis of this data as well as other studies need to be conducted to draw firm conclusions, however this study does affirm other similar studies on student-to-student talk (e.g.; de los Santos, 2011; Duschl & Osborne, 2002; Mortimer & Scott, 2003; Osborne et al., 2013). Those studies were conducted with various populations such as English as a second language communities, in other countries thus different languages, or comparing ESL to Native speakers of English. The de los Santos (2011) study showed an importance of identity and authority in learning science as well as the occurrence of productive conversation and talk across contexts, just as the current study has highlighted in a different population.

Now that I have experience in using this style of DA and a refined definition of SSPT, further studies can be planned and even this data could be revisited to form stronger conclusions.

Some other possible future research could be the study of distinct portions of the labs recorded, such as the pre-lab, in-lab, and some concluding portions. These were recorded for some of these labs. A closer analysis of the discourse patterns might prove interesting and insightful since most previous studies were done with only pairs of students, or teacher-student pairs. A full conversation analysis of individual representative conversations may prove fruitful in distinguishing the nuances of a group of three students versus a pair and may give interesting results. And of course, the repetition of the study with larger sample sizes, either more groups or more time or more labs, could also solidify the gained knowledge represented here.

As mentioned in Chapter III, there were several questions that arose while analyzing the data. This is both exciting and frustrating, in that this study needs to have a complete narrative and answer the research questions in a timely manner, but in the answering of these research questions, only more questions were generated. For example, reanalyzing the data based on the information about identity and authority may prove fruitful. This is an exciting prospect in that even more could be drawn from a seemingly small sample of the conversations of these eight students, but frustrating in the way that this one project cannot give what could possibly become stronger answers in a longer period of study. The development of a way to discern the level of dialogic pedagogy occurring in a classroom might prove useful in future studies.

REFERENCES

Abd Elkader, N. (2014). Epistemological Approaches to Dialogic Teaching in a Conventional Setting—Critical Review. *Dialogic Pedagogy: An International Online Journal*, *2*(Journal Article). https://doi.org/10.5195/dpj.2014.83

Adams, M., & March, S. (2015). Perezhivanie and classroom discourse: A cultural–historical perspective on "Discourse of design based science classroom activities." *Cultural Studies of Science Education*, *10*(2), 317–327. https://doi.org/10.1007/s11422-014-9574-3

Aguiar, O. G. (2016). Explanation, argumentation and dialogic interactions in science classrooms. *Cultural Studies of Science Education*, *11*(4), 869–878. https://doi.org/10.1007/s11422-015-9694-4

Alexander, R. (2008). *Towards Dialogic Teaching: Rethinking Classroom Talk* (4th ed.). Dialogos UK Ltd.

Alexander, Robin. (2020). *A Dialogic Teaching Companion*. Routledge. https://doi.org/10.4324/9781351040143

Alfonseca, E., Carro, R. M., Martín, E., Ortigosa, A., & Paredes, P. (2006). The impact of learning styles on student grouping for collaborative learning: A case study. *User Modeling and User-Adapted Interaction*, *16*(3–4), 377–401. https://doi.org/10.1007/s11257-006-9012-7

Alozie, N. M., Moje, E. B., & Krajcik, J. S. (2009). An analysis of the supports and constraints for scientific discussion in high school project-based science. *Science Education*, n/a-n/a. https://doi.org/10.1002/sce.20365

Baker, A. T., & Beames, S. (2016). Good CoP: What makes a community of practice successful? *Journal of Learning Design*, *9*(1), 72. https://doi.org/10.5204/jld.v9i1.234

Bakhtin, M. M. (1981). *Bakhtin, M.M. The dialogic imagination* (M. Holquist, Ed.). University of Texas Press.

Bakhtin, M. M. (Mikhail M., 1895-1975. (2004). Dialogic Origin and Dialogic Pedagogy of Grammar: Stylistics in Teaching Russian Language in Secondary School. *Journal of Russian and East European Psychology*, *42*(6), 12–49. https://doi.org/10.1080/10610405.2004.11059233

Bakhtin, M. M. (Mikhail M., 1895-1975, & Holquist, M., 1935. (1981). *The dialogic imagination: Four essays*. University of Texas Press.

Ballenger, C. (1997). Social Identities, Moral Narratives, Scientific Argumentation: Science Talk in a Bilingual Classroom. *Language and Education*, *11*(1), 1–14. https://doi.org/10.1080/09500789708666715

Barnes, D. R. (1976). *From communication to curriculum*. Penguin Education.

Barton, A. C., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a Future in Science: Tracing Middle School Girls' Identity Work Over Time and Space. *American Educational Research Journal*, *50*(1), 37–75. https://doi.org/10.3102/0002831212458142

Bernot, M., & Metzler, J. (2014). A Comparative Study of Instructor- and Student-Led Learning in a Large Nonmajors Biology Course: Student Performance and Perceptions. *Journal of College Science Teaching*, *044*(01). https://doi.org/10.2505/4/jcst14_044_01_48

Bignell, C. (n.d.). *A Dialogic Endeavour: A study of three newly qualified teachers' journeys "towards dialogic teaching."* 268.

Birks, M., & Mills, J. (2015). *Grounded Theory: A Practical Guide*. SAGE Publications.

Boyd, M. P., & Markarian, W. C. (2015). Dialogic Teaching and Dialogic Stance: Moving beyond Interactional Form. *Research in the Teaching of English*, *49*(3), 272–296.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What Kind of a Girl Does Science? The Construction of School Science Identities. *Journal of Research in Science Teaching*, *37*(5), 441–458. https://doi.org/10.1002/(SICI)1098-2736(200005)37:5<441::AID-TEA4>3.0.CO;2-3

Brooks, L. A., & Dixon, J. K. (2013). Changing the Rules to Increase Discourse. *Teaching Children Mathematics*, *20*(2), 84–89. a9h.

Brown, A. C. (2016). Classroom community and discourse: How argumentation emerges during a Socratic circle. *Dialogic Pedagogy: An International Online Journal*, *4*. https://doi.org/10.5195/DPJ.2016.160

Brown, B. (2010). *The gifts of imperfection: Let go of who you think you're supposed to be and embrace who you are*. Hazelden.

Bruner, J. (1987). *Actual Minds, Possible Worlds*. Harvard University Press. http://ebookcentral.proquest.com/lib/uark-ebooks/detail.action?docID=3300334

Bryant, A., & Charmaz, K. (2010). Grounded Theory. *International Encyclopedia of Education*, *6*(Generic), 406–412.

Byhring, A. K., & Knain, E. (2014). Framing student dialogue and argumentation: Content knowledge development and procedural knowing in SSI inquiry group work. *Nordic Studies in Science Education*, *10*(2), 146. https://doi.org/10.5617/nordina.661

Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching*, *41*(4), 392–414. https://doi.org/10.1002/tea.20006

Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning. 2. Ed*. Heinemann.

Chan, J. Y. K., & Bauer, C. F. (2015). Effect of peer-led team learning (PLTL) on student achievement, attitude, and self-concept in college general chemistry in randomized and quasi experimental designs. *Journal of Research in Science Teaching*, *52*(3), 319–346. https://doi.org/10.1002/tea.21197

Charmaz, K. (2006). Constructing grounded theory: A practical guide through qualitative analysis. In *Constructing Grounded Theory*. SAGE Publications.

Chin, C., & Osborne, J. (2008). Students' questions: A potential resource for teaching and learning science. *Studies in Science Education*, *44*(1), 1–39. https://doi.org/10.1080/03057260701828101

Christodoulou, A., & Osborne, J. (2014). The science classroom as a site of epistemic talk: A case study of a teacher's attempts to teach science based on argument: THE SCIENCE CLASSROOM AS A SITE OF EPISTEMIC TALK. *Journal of Research in Science Teaching*, *51*(10), 1275–1300. https://doi.org/10.1002/tea.21166

Clark, S. K., & Lott, K. (2017). Integrating Science Inquiry and Literacy Instruction for Young Children. *The Reading Teacher*, *70*(6), 701–710. https://doi.org/10.1002/trtr.1572

Clarke, S. (2015). The Right to Speak. In L. Resnick, C. Asterhan, & S. Clarke (Eds.), *Socializing Intelligence Through Academic Talk and Dialogue* (Vol. 1–Book, Section). Casemate Publishers & Book Distributors.

Clift, R. (2016). *Conversation Analysis*. Cambridge University Press; Cambridge Core. https://doi.org/10.1017/9781139022767

Colley, C., & Windschitl, M. (2016). Rigor in Elementary Science Students' Discourse: The Role of Responsiveness and Supportive Conditions for Talk: ROLE OF SUPPORTIVE CONDITIONS IN STUDENT DISCOURSE. *Science Education*, *100*(6), 1009–1038. https://doi.org/10.1002/sce.21243

Craddock, J. L. (2017). *The Perceptions of Elementary School Teachers Regarding Their Efforts to Help Students Utilize Student-to-Student Discourse in Science*. ProQuest Dissertations Publishing.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (Third). SAGE Publications.

Criswell, B. A. (2009). *Inquiry in conversation: Exploring the multiple solution pathway (MSP) lesson structure as a means to progressive discourse in the science classroom*. ProQuest Dissertations Publishing.

de los Santos, X. (2011). *Science talk: Students' patterns of interaction in a chemistry classroom* (904581242) [M.S., California State University, Long Beach]. ProQuest Central. http://0-search.proquest.com.library.uark.edu/docview/904581242?accountid=8361

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84*(3), 287–312. https://doi.org/10.1002/(SICI)1098-237X(200005)84:3<287::AID-SCE1>3.0.CO;2-A

Duschl, R. (2008). Science Education in Three-Part Harmony: Balancing Conceptual, Epistemic, and Social Learning Goals. *Review of Research in Education*, *32*, 268–291.

Duschl, R. A., & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education*, *38*(1), 39–72. https://doi.org/10.1080/03057260208560187

Egglezou, F. (2016). Bakhtin's Influence: A Dialogic Approach to Teaching of Argumentation / Bahtin'in Etkisi: Argümantasyon Öğretiminde Diyalog Temelli Bir Yaklaşım. *Ana Dili Eğitimi Dergisi*, *4*(1), 1–14. https://doi.org/10.16916/aded.03040

Elizabeth, T., Ross Anderson, T. L., Snow, E. H., & Selman, R. L. (2012). Academic Discussions: An Analysis of Instructional Discourse and an Argument for an Integrative Assessment Framework. *American Educational Research Journal*, *49*(6), 1214–1250. https://doi.org/10.3102/0002831212456066

Farland-Smith, D. (2009). Exploring Middle School Girls' Science Identities: Examining Attitudes and Perceptions of Scientists when Working "Side-by-Side" with Scientists. *School Science and Mathematics*, *109*(7), 415–427. https://doi.org/10.1111/j.1949-8594.2009.tb17872.x

Felton, M., Garcia-Mila, M., Villarroel, C., & Gilabert, S. (2015). Arguing collaboratively: Argumentative discourse types and their potential for knowledge building. *British Journal of Educational Psychology*, *85*(3), 372–386. https://doi.org/10.1111/bjep.12078

Ford, M., & Forman, E. (2015). Uncertainty and Scientific Progress in Classroom Dialogue. In L. Resnick, C. Asterhan, & S. Clarke (Eds.), *Socializing Intelligence Through Academic Talk and Dialogue* (Vol. 1–Book, Section). Casemate Publishers & Book Distributors.

Friend, L. (2017). IRE and content area literacies: A critical analysis of classroom discourse. *Australian Journal of Language and Literacy*, *40*(2), 124–134.

Geban, O., Askar, P., & Ozkan, I. (1992). Effects of computer simulations and problem solving approaches on high school students. *Journal of Educational Research*, *86*(1), 5–10.

Gee, J. P. (2014a). *An introduction to discourse analysis: Theory and method* (Fourth). Routledge.

Gee, J. P. (2014b). *How to do Discourse Analysis: A Toolkit* (2nd; 2nd ed.). Routledge. https://doi.org/10.4324/9781315819662

Giest, H. & L., J. (2003). Formation of Learning Activity and Theoretical Thinking in Science Teaching. In A. Kozulin, B. Gindis, V. Ageyev, & S. Miller (Eds.), *Vygotsky's Educational Theory in Cultural Context* (Vol. 1–Book, Section, pp. 267–288). Cambridge University Press.

Glaser, B. G., & Strauss, A. L. (2017). *The discovery of grounded theory: Strategies for qualitative research* (Kindle). Taylor & Francis.

Griswold, J., Shaw, L., & Munn, M. (2017). Socratic Seminar with Data: A Strategy to Support Student Discourse and Understanding. *The American Biology Teacher*, *79*(6), 492–495. https://doi.org/10.1525/abt.2017.79.6.492

Hajhosseiny, M. (2012). The Effect of Dialogic Teaching on Students' Critical Thinking Disposition. *Procedia - Social and Behavioral Sciences*, *69*, 1358–1368. https://doi.org/10.1016/j.sbspro.2012.12.073

Hammersley, M. (2003). Conversation Analysis and Discourse Analysis: Methods or Paradigms? *Discourse & Society*, *14*(6), 751–781.

Haneda, M. (2017). Dialogic learning and teaching across diverse contexts: Promises and challenges. *Language and Education*, *31*(1), 1–5. https://doi.org/10.1080/09500782.2016.1230128

Hofstein, A. (2015). The Development of High-Order Learning Skills in High School Chemistry Laboratory: "Skills for Life." In *Chemistry Education* (Vol. 1–Book, Section, pp. 517–538). Wiley-VCH Verlag GmbH & Co. KGaA. https://doi.org/10.1002/9783527679300.ch21

Hofstein, A., & Lunetta, V. N. (1980). *The Role of the Laboratory in Science Teaching: Research Implications*.

Hofstein, A., & Lunetta, V. N. (1982). The Role of the Laboratory in Science Teaching: Neglected Aspects of Research. *Review of Educational Research*, *52*(2), 201. https://doi.org/10.2307/1170311

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education (Salem, Mass.)*, *88*(1), 28–54. https://doi.org/10.1002/sce.10106

Hofstein, A., & Lunetta, V. N. (2016). The Role of the Laboratory in Science Teaching: Neglected Aspects of Research. *Review of Educational Research*, *52*(2), 201–217. https://doi.org/10.3102/00346543052002201

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching*, *42*(7), 791–806. https://doi.org/10.1002/tea.20072

Holland, D., Lachicotte, Jr., W., Skinner, D., & Cain, C. (1998). *Identity and Agency in Cultural Worlds*. Harvard University Press.

Howe, C. (2010). Peer Dialogue and Cognitive Development: A Two-way Relationship? In K. Littleton & C. Howe (Eds.), *Educational Dialogues: Understanding and Promoting Productive interaction* (1st ed., Vol. 1–Book, Section, pp. 32–47). Routledge Ltd. https://doi.org/10.4324/9780203863510

Howe, C., & Abedin, M. (2013). Classroom dialogue: A systematic review across four decades of research. *Cambridge Journal of Education*, *43*(3), 325–356. https://doi.org/10.1080/0305764X.2013.786024

Hsu, P.-L., Roth, W.-M., & Mazumder, A. (2009). Natural pedagogical conversations in high school students' internship. *Journal of Research in Science Teaching*, *46*(5), 481–505. https://doi.org/10.1002/tea.20275

Hughes, R., Schellinger, J., & Roberts, K. (2021). The role of recognition in disciplinary identity for girls. *Journal of Research in Science Teaching*, *58*(3), 420–455. https://doi.org/10.1002/tea.21665

Jay, T., Willis, B., Thomas, P., Taylor, R., Moore, N., Burnett, C., Merchant, G., & Stevens, A. (2017). *Dialogic Teaching: Evaluation report and executive summary* (p. 77). Education Endowment Foundation.

Jefferson, G. (1974). Error correction as an interactional resource. *Language in Society*, *3*(2), 181–199. https://doi.org/10.1017/S0047404500004334

Jefferson, G. (1984). Transcription Notation. In J. Atkinson & J. Heritage (Eds.), *Structures of Social Interaction*. Cambridge University Press.

Jefferson, G. (1985). On the interactional unpackaging of a 'gloss.' *Language in Society*, *14*(4), 435–466. https://doi.org/10.1017/S0047404500011465

Jefferson, G. (1996). On the poetics of ordinary talk1. *Text and Performance Quarterly*, *16*(1), 1–61. https://doi.org/10.1080/10462939609366132

Jefferson, G., & Schenkein, J. (1977). Some Sequential Negotiations in Conversation: Unexpanded and Expanded Versions of Projected Action Sequences. *Sociology*, *11*(1), 87–103.

Kaya, S. (2014). Examining question type and the timing of IRE pattern in elementary science classrooms. *International Journal of Human Sciences*, *11*(1), 621–641. https://doi.org/10.14687/ijhs.v11i1.2730

Kelly, G. J., Cunningham, C. M., & Ricketts, A. (2017). Engaging in identity work through engineering practices in elementary classrooms. *Linguistics and Education*, *39*, 48–59. https://doi.org/10.1016/j.linged.2017.05.003

Kuhn, D., & Crowell, A. (2011). Dialogic Argumentation as a Vehicle for Developing Young Adolescents' Thinking. *Psychological Science*, *22*(4), 545–552. https://doi.org/10.1177/0956797611402512

Kuhn, D., & Dean, J., David. (2004). Metacognition: A Bridge Between Cognitive Psychology and Educational Practice. *Theory Into Practice*, *43*(4), 268–273. https://doi.org/10.1207/s15430421tip4304_4

Kuhn, T. (1962). *The Structure of Scientific Revolutions: 50th Anniversary Edition* (4th ed.). University of Chicago Press.

Kumpulainen, K., & Lipponen, L. (2010). Produtive Interaction as Agentic Participation in Dialogic Enquiry. In K. Littleton & C. Howe (Eds.), *Educational Dialogues: Understanding and Promoting Productive interaction* (1st ed., Vol. 1–Book, Section, pp. 48–63). Routledge Ltd. https://doi.org/10.4324/9780203863510

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.

Lee, Y.-J. (2012). Identity-Based Research in Science Education. In B. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (Vol. 24, pp. 35–46). Springer International Publishing.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Ablex Pub. Corp.

MacCabe, C., Yanacek, H., & The Keywords Project. (2018). *Keywords for today: A 21st century vocabulary*.

McComas, W. F. (Ed.). (2014). *The Language of Science Education: An Expanded Glossary of Key Terms and Concepts in Science Teaching and Learning*. Sense Publishers.

Mehan, H., 1941. (1979). *Learning lessons: Social organization in the classroom*. Harvard University Press.

Mercer, N. (2004). Sociocultural discourse analysis: Analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics*, *1*(2), 137–168. https://doi.org/10.1558/japl.2004.1.2.137

Mercer, N., Dawes, L., & Staarman, J. K. (2009). Dialogic teaching in the primary science classroom. *Language and Education*, *23*(4), 353–369. https://doi.org/10.1080/09500780902954273

Mercer, N., Hennessy, S., & Warwick, P. (2017). Dialogue, thinking together and digital technology in the classroom: Some educational implications of a continuing line of inquiry. *International Journal of Educational Research*. https://doi.org/10.1016/j.ijer.2017.08.007

Mestad, I., & Kolstø, S. D. (2014). Using the Concept of Zone of Proximal Development to Explore the Challenges of and Opportunities in Designing Discourse Activities Based on Practical Work. *Science Education*, *98*(6), 1054–1076.

Moon, A., Stanford, C., Cole, R., & Towns, M. (2017). Decentering: A Characteristic of Effective Student–Student Discourse in Inquiry-Oriented Physical Chemistry Classrooms. *Journal of Chemical Education*, *94*(7), 829–836. https://doi.org/10.1021/acs.jchemed.6b00856

Moore, F. M. (2007). Language in Science Education as a Gatekeeper to Learning, Teaching, and Professional Development. *Journal of Science Teacher Education*, *18*(2), 319–343. https://doi.org/10.1007/s10972-007-9040-0

Morris, P. (1994). *The Bakhtin Reader: Selected Writings of Bakhtin, Medvedev, Voloshinov*. St. Martin's Press.

Mortimer, E. F., & Scott, P. (2003). *Meaning making in secondary science classrooms* (Kindle Edition). Open University Press.

Nassaji, H. (2000). What's the use of "triadic dialogue"?: An investigation of teacher-student interaction. *Applied Linguistics*, *21*(3), 376–406. https://doi.org/10.1093/applin/21.3.376

Next Generation Science Standards. (n.d.). Retrieved December 9, 2018, from https://www.nextgenscience.org/

Nystrand, M., Wu, L., Gamoran, A., Zeiser, S., & Long, D. A. (2003). Questions in time: Investigating the structure and dynamics of unfolding classroom discourse. *Discourse Processes*, *35*(2), 135–200.

Osborne, J., & Chin, C. (2010). The Role of Discourse in Learning Science. In K. Littleton & C. Howe (Eds.), *Educational Dialogues: Understanding and Promoting Productive interaction* (1st ed., Vol. 1–Book, Section, pp. 88–102). Routledge Ltd. https://doi.org/10.4324/9780203863510

Osborne, J., Simon, S., Christodoulou, A., Howell-Richardson, C., & Richardson, K. (2013). Learning to argue: A study of four schools and their attempt to develop the use of argumentation as a common instructional practice and its impact on students. *Journal of Research in Science Teaching*, *50*(3), 315–347. https://doi.org/10.1002/tea.21073

PhET Interactive Simulations. (n.d.). PhET. Retrieved August 5, 2020, from https://phet.colorado.edu/

Piaget, J. (1932a). *The Language and Thought of the Child, 1926; Judgment and Reasoning in the Child, 1928; The Child's Conception of the World, 1929; The Child's Conception of Physical Causality, 1930; The Moral Judgment of the Child, 1932*. Harcourt, Brace.

Piaget, J. (1932b). *The moral judgment of the child*. Harcourt, Brace.

Piaget, Jean, 1896-1980. (1959). *The language and thought of the child* (3d [rev. and enl.]). Routledge & K. Paul.

Piaget, Jean, 1896-1980. (1965). *The moral judgment of the child*. Free Press.

Polman, J. L., & Pea, R. D. (2001). Transformative communication as a cultural tool for guiding inquiry science. *Science Education*, *85*(3), 223–238. https://doi.org/10.1002/sce.1007

Preszler, R. W. (2009). Replacing Lecture with Peer-led Workshops Improves Student Learning. *CBE-Life Sciences Education*, *8*(3), 182–192. https://doi.org/10.1187/cbe.09-01-0002

Puntambekar, S., Gnesdilow, D., Dornfeld Tissenbaum, C., Narayanan, N. H., & Rebello, N. S. (2021). Supporting middle school students' science talk: A comparison of physical and virtual labs. *Journal of Research in Science Teaching*, *58*(3), 392–419. https://doi.org/10.1002/tea.21664

Resnick, L., Asterhan, C., & Clarke, S. (2015). *Socializing Intelligence Through Academic Talk and Dialogue*. American Educational Research Association.

Reznitskaya, A. (2012). Dialogic Teaching: Rethinking Language Use During Literature Discussions. *The Reading Teacher*, *65*(7), 446–456. https://doi.org/10.1002/trtr.01066

Reznitskaya, A., Glina, M., Carolan, B., Michaud, O., Rogers, J., & Sequeira, L. (2012). Examining transfer effects from dialogic discussions to new tasks and contexts. *Contemporary Educational Psychology*, *37*(4), 288–306. https://doi.org/10.1016/j.cedpsych.2012.02.003

Reznitskaya, A., & Gregory, M. (2013). Student Thought and Classroom Language: Examining the Mechanisms of Change in Dialogic Teaching. *Educational Psychologist*, *48*(2), 114–133. https://doi.org/10.1080/00461520.2013.775898

Rivera Maulucci, M. S., Brown, B. A., Grey, S. T., & Sullivan, S. (2014). Urban middle school students' reflections on authentic science inquiry: STUDENTS' REFLECTIONS ON AUTHENTIC SCIENCE INQUIRY. *Journal of Research in Science Teaching*, *51*(9), 1119–1149. https://doi.org/10.1002/tea.21167

Rocksén, M. (2016). The many roles of "explanation" in science education: A case study. *Cultural Studies of Science Education*, *11*(4), 837–868. https://doi.org/10.1007/s11422-014-9629-5

Rogers, T., Marshall, E., & Tyson, C. A. (2006). Dialogic Narratives of Literacy, Teaching, and Schooling: Preparing Literacy Teachers for Diverse Settings (Narrativas dialógicas en alfabetización, enseñanza y escolaridad: Preparando a los docentes de lectoescritura para contextos diversos) *Reading Research Quarterly*, *41*(2), 202–224. https://doi.org/10.1598/RRQ.41.2.3

Roth, W.-M. (2009). *Dialogism: A Bakhtinian Perspective on Science and Learning* (Vol. 15). Sense Publishers. https://doi.org/10.1163/9789087908645

Rymes, B. (2016). *Classroom discourse analysis: A tool for critical reflection* (Second). Routledge.

Sacks, H., Schegloff, E. A., & Jefferson, G. (1974). A Simplest Systematics for the Organization of Turn-Taking for Conversation. *Language*, *50*(4), 696–735. https://doi.org/10.1353/lan.1974.0010

Schegloff, E. A. (1999). Discourse, pragmatics, conversation, analysis. *Discourse Studies*, *1*(4), 405–435. https://doi.org/10.1177/1461445699001004002

Schegloff, E. A., & Sacks, H. (1973). Opening Up Closings. *Semiotica: Journal of the International Association for Semiotic Studies/Revue de l'Association Internationale*, *8*(4), 289. https://doi.org/10.1515/semi.1973.8.4.289

Schiffrin, D. (1994). *Approaches to discourse: Vol. 8;8.;* B. Blackwell.

Schuitema, J., van Boxtel, C., Veugelers, W., & ten Dam, G. (2011). The quality of student dialogue in citizenship education. *European Journal of Psychology of Education*, *26*(1), 85–107. https://doi.org/10.1007/s10212-010-0038-1

Schwarz, B. B., & Shahar, N. (2017). Combining the dialogic and the dialectic: Putting argumentation into practice in classroom talk. *Learning, Culture and Social Interaction*, *12*, 113–132. https://doi.org/10.1016/j.lcsi.2016.12.003

Smart, J. B., & Marshall, J. C. (2013). Interactions Between Classroom Discourse, Teacher Questioning, and Student Cognitive Engagement in Middle School Science. *Journal of Science Teacher Education*, *24*(2), 249–267. https://doi.org/10.1007/s10972-012-9297-9

Snyder, J. J., Sloane, J. D., Dunk, R. D. P., & Wiles, J. R. (2016). Peer-Led Team Learning Helps Minority Students Succeed. *PLoS Biology*, *14*(3), e1002398. https://doi.org/10.1371/journal.pbio.1002398

Stake, R. E. (2010). *Qualitative research: Studying how things work*. Guilford Press.

Strauss, S., & Feiz, P. (2014). *Discourse Analysis*. Routledge. https://doi.org/10.4324/9780203121559

Thwaite, A., & McKay, G. (2013). Five-year olds doing science and technology: How teachers shape the conversation. *Australian Journal of Language and Literacy, The*, *36*(1), 28–37.

Uzuner Smith, S., & Mehta, R. (2013). The Educational Value of Student Talk in Online Discussions. In C. Meskill (Ed.), *Online Teaching and Learning* (Vol. 1–Book, Section, pp. 119–136). Bloomsbury Publishing Plc. https://doi.org/10.5040/9781472542007.ch-006

vanZee, E., & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *INTERNATIONAL JOURNAL OF SCIENCE EDUCATION*, *19*(2), 209–228.

Varelas, M., Pappas, C. C., & Arsenault, A. (2013). *Children's Ways with Science and Literacy: Integrated Multimodal Enactments in Urban Elementary Classrooms*. Routledge Ltd. https://doi.org/10.4324/9780203076910

Veen, M., & de la Croix, A. (2017). The swamplands of reflection: Using conversation analysis to reveal the architecture of group reflection sessions. *Medical Education*, *51*(3), 324–336. https://doi.org/10.1111/medu.13154

Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching*, n/a-n/a. https://doi.org/10.1002/tea.20358

Volet, S., Vauras, M., Salo, A.-E., & Khosa, D. (2017). Individual contributions in student-led collaborative learning: Insights from two analytical approaches to explain the quality of group outcome. *Learning and Individual Differences*, *53*(Journal Article), 79–92. https://doi.org/10.1016/j.lindif.2016.11.006

von Aufschnaiter, C., Erduran, S., Osborne, J., & Simon, S. (2008). Arguing to learn and learning to argue: Case studies of how students' argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching*, *45*(1), 101–131. https://doi.org/10.1002/tea.20213

Vygotsky, L. S. (1934). *Thinking and Speech*. https://www.marxists.org/archive/vygotsky/works/words/Thinking-and-Speech.pdf

Vygotsky, L. S. (1962). *Thought and Language*. MIT Press.

Vygotsky, L. S. (1978). *Mind in Society*. Harvard University Press.

Wallace, C. S. (2004). Framing new research in science literacy and language use: Authenticity, multiple discourses, and the Third Space. *Science Education*, *88*(6), 901–914. https://doi.org/10.1002/sce.20024

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A., & Hudicourt-Barnes, J. (2001). Rethinking Diversity in Learning Science: The Logic of Everyday Sense-Making. *JOURNAL OF RESEARCH IN SCIENCE TEACHING*, *38*(5), 529–552.

Watters, J. J., & Diezmann, C. M. (2016). Engaging elementary students in learning science: An analysis of classroom dialogue. *Instructional Science*, *44*(1), 25–44. https://doi.org/10.1007/s11251-015-9364-7

Webb, N. M. (2009). The teacher's role in promoting collaborative dialogue in the classroom. *British Journal of Educational Psychology*, *79*(1), 1–28. https://doi.org/10.1348/000709908X380772

Webb, N. M., Franke, M. L., De, T., Chan, A. G., Freund, D., Shein, P., & Melkonian, D. K. (2009). 'Explain to your partner': Teachers' instructional practices and students' dialogue in small groups. *Cambridge Journal of Education*, *39*(1), 49–70. https://doi.org/10.1080/03057640802701986

Wellington, J. J., & Osborne, J. (2001). *Language and literacy in science education*. Open University.

Wells, C. G. (1999). *Dialogic inquiry: Towards a sociocultural practice and theory of education*. Cambridge University Press.

Wells, G., & Arauz, R. M. (2006). Dialogue in the Classroom. *The Journal of the Learning Sciences*, *15*(3), 379–428.

Wenning, C. J. (2009). *Scientific epistemology: How scientists know what they know*. 14.

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Harvard University Press.

White, B. (2015). Scapegoat: John Dewey and the character education crisis. *Journal of Moral Education*, *44*(2), 127–18. https://doi.org/10.1080/03057240.2015.1028911

Wilcox, J., Kruse, J. W., & Clough, M. P. (2015). Seven common myths about this time-honored approach. *The Science Teacher*, 8.

Yerrick, R., & Roth, W.-M. (2005). *Establishing Scientific Classroom Discourse Communities: Multiple Voices of Teaching and Learning Research*. Lawrence Erlbaum Associates.

Young, K. K., & Talanquer, V. (2013). Effect of Different Types of Small-Group Activities on Students' Conversations. *Journal of Chemical Education*, *90*(9), 1123–1129. https://doi.org/10.1021/ed400049a

APPENDICES

Appendix 1: Summary of Instructions for the Laboratory Activities Observed and Analyzed

The following pages include the lab worksheets and instructions for all four labs that were recorded during the duration of this investigation. In order in order of recording, there is Levers 'R' Us, PhET Atom Simulator, Families of Elements, and Flames labs. Herron (1971) and Schwab (1962) set a 0-3 level system for defining the cognitive load of a lab, this information will be given for each lab.

Levers 'R'Us Lab (LRU)

The Levers 'R'Us lab required the students to explore first-, second-, and third-class levers. Using various common items, the students are to build a working version of the three types of levers. Once built, the students took various measurements to prove the change in the needed effort to lift certain loads. The lab had a set of pre-lab questions that had them identify the types of levers in the human body (arms and legs) and the muscles involved. Then after the measurements were taken from the built levers, they had a series of conclusionary questions to answer that required justification for their answers as well as some questions using force equations with different parts to be solved. This would be a level 2 lab since the actual building of the levers was left up to the students to decide, in both how to build them and what materials to use.

PhET Atom Simulation

The PhET Simulation Lab was an atom simulator where students were asked to build various versions of a helium atom and note the changes when electrons, neutrons and protons were added or taken away. They were then to simulate three elements of their choice recording various information such as the atomic number and mass of what they created. In part two, they explored ions and isotopes to see which particles effected certain changes in the elemental atom. For the final part of the activity, there were four games written in the simulation for the students to play and try to achieve a perfect score for each. This is a level 1 lab, due to the instructional nature of the worksheet. It had direct instructions to add or remove a certain number of electrons, though the answers were still open to the students to make their own conclusions.

Families of Elements (FOE)

For the Families of Elements lab, the students are required to identify elements in the same family based on how they form compounds. The properties of the compounds were observed in a chem plate by placing various ratios of silver nitrate solution with four different solutions of potassium (chloride, bromide, iodine, and sulfide) and noting the ratio that produced the most precipitate. The lab was concluded with comprehension questions about the chemical compounds made as well as possible sources of error and safety rules. This was the first chemistry lab of the chemistry unit, so it was necessary to review lab safety and to acclimate the students in the new laboratory setting in the new building. This lab was also a level 1 lab because the procedure was given, although with the risks of dealing with chemicals, it is logical to have a set procedure in place.

Flames Lab

For the Flames lab, the students tested the levels of excitement in electrons of various elements by burning a small amount of 4 known metallic elements and observing the colors of the flames. They were then given one unknown element which was burned, and identified based on the observations of the known ions. The lab was concluded with the students being required to answer comprehension questions as well as give definitions of terms and identify sources and types of error. This was a level 2 lab because there were not specific procedures given on the process of identifying the chemicals, other than a verbal instruction to use the water to put out the flames after observation.

Appendix 2: Example Conversations

The following are example conversations which were discussed in Chapter V. These were referenced as examples for the discussion of the research questions and implications for future research. They helped develop the possible final theory of this grounded theory study.

Table A

Example Open Chain Conversations to be discussed in Chapter V

Conversation 1	Families of Elements
Andrew:	All right, which one am I looking for again?
Brian:	Uh, bromide.
Andrew:	Bromide?
Brian:	Okay, and here's a trick that I know you all don't know yet-
Andrew:	Oh, crap.
Connie:	Found it.
Andrew:	I found baru...ree-you-ma.
Connie:	It's BR.
Brian:	Yeah.
Andrew:	BR? All right, what was it, Connie?
Brian:	Oh, so on your paper, they end in "I-D-E", but on your periodic table, they're going to end in "I-N-E". Way more on that cup. But the endings of them are a little different, but that's okay just keep going.
Andrew:	All right.
Brian:	I promise to explain.
Andrew:	Okay.
Brian:	Yo, Io-
Andrew:	Iodide.
Brian:	Iodide. Would not be iodide.
Andrew:	Iodide.
Brian:	Iodide, yes.
Andrew:	Iodide, okay. Iodide.
Brian:	I found it
Andrew:	You found iodide?

Conversation 2 Flames

Felicia: Keep an eye on it okay?

Dawn: Okay.

Dawn: Do you want me to put it over?

Felicia: Keep an eye on it okay?

Dawn: Mm-hmm (affirmative).

Felicia: She's passing it out [inaudible 00:07:38]

Dawn: Wait is this S-R?

Felicia: Yes.

Felicia: Can I do the last one?

Dawn: How are we going to do this one?

Felicia: Can I see it?

Felicia: Oh that's cool.

Erin: It's like really orange.

Erin: Okay that's kind of weird.

Dawn: My arm just catches on fire. (laughter)

Erin: Like that.

Erin: Its like really orange and black.

Dawn: Its more orangy.

Conversation 3 Families of Elements

Connie: Why is this one weird? Look at it. It's so different than all the others, all of them are so different. Why is this how the way that it is? Eww. So, this one's the least clear.

Andrew: So, it goes from clear to Dr. Pepper color.

Brian: So it's gonna be six five, seven five?

Connie: Shut up its seven five.

Brian: Geeze, you don't have to get freaking mad, Connie.

Conversation 4 LRU

Connie: Second we got two-

Brian: Mean review.

Connie: Oh, just a sec. The effort is between the resistance and fulcrum.

Brian: Since we got first and second on there, it's obviously the sec-, the negative zero.

Connie: Third.

Brian: I would never have guessed that.

Connie: Third and negative zero are the same. Identify the muscles present in each of the human body lever systems any way you do it.

Brian: How am I supposed to know this?

Connie:	Well, I mean-
Brian:	You got an arm, a, a leg.
Connie:	No, this is muscles.
Brian:	Oh.
Connie:	I-I'm trying to decide what these are.
Brian:	So what, you got the... All right, arm muscles. I'm just gonna go check, show me [inaudible 00:12:36]
Connie:	Well, I don't think that's what we're looking for (laughs).
Brian:	(Laughs) It's close enough. But you got to hang that thing there, you got some
Connie:	There should only... Identify the muscles present. See, it only wants us to put three muscles. What?
Brian:	There are more than three muscles. There's one, two-
Connie:	Yeah, I, I...
Brian:	... three, four, five, six, seven, eight muscles. Nine... Yeah, there's like eight and nine different types... There's a lot of muscles on the human body. Why are we so complex?

Table B

Example Closed Chain Conversations to be discussed in Chapter V

Conversation 5	Atom Sim
Connie:	So is that like, it?
Brian:	Okay, following the direc- follow the directions. Observe what happens to the table below. Okay. How does it change the overall charge? Where's the...
Connie:	The net charge?
Andrew:	Let's just add everything in. See what we get.
Connie:	It doesn't...
Brian:	I think net is your overall, like, worth in money. So, I think that would be net.
Andrew:	Net?
Brian:	Yeah, like your net worth.
Andrew:	Wait what's this, what's this-
Connie:	Our mass is four.
Andrew:	Wasn't I supposed to... Oh.
Brian:	So okay. Overall, how does it change the overall charge?
Connie:	I think the charge did...
Brian:	It doesn't?

Connie: The charge didn't change.

Brian: Did I, I, I'm just gonna say, "Don't." I don't know.

Andrew: Overall charge... Done.

Conversation 6 LRU

Andrew: Let's do this.

Brian: That is lit AF.

Connie: {inaudible 00:06:51}

Andrew: Stop.

Connie: {inaudible 00:06:53} like the law.

Brian: Okay.

Connie: Been quite some time since I {crosstalk 00:06:57}

Brian: How many did we use?

Connie: Um.

Andrew: I don't know.

Connie: Well, let's look, guys.

Andrew: Which is awesome. {crosstalk 00:07:04}

Brian: It doesn't tell us how many to use. It just tells us to use stuff.

Andrew: Let's not use all of them, though.

Brian: Yeah, why don't we just use four.

Connie: I think four {crosstalk 00:07:11} okay, okay. Four {inaudible 00:07:13} I got four right here.

Brian: I already started. {crosstalk 00:07:18} (singing)

Connie: That would be, like, so much easier if you did it another way that is not that.

Conversation 7 Atom Sim

Connie: So are we watch'in it?

Brian: Click it.

Andrew: No, I'm not good.

Connie: Okay.

Andrew: Mine's still turnin' on. Like the lit boy I am.

Brian: Okay.

Andrew: Oh, crap.

Brian: Um, okay, so I'm guessing we go to this one 'cause that's what it shows.

Connie: So click on the plus sign. Okay, okay, so click on atom, I guess. Okay. Uh...

Andrew: Is this where the Adam family comes from?

Brian: Okay.

Connie: Building the-

53	Brian:	So click on the plus sign for each of the boxes.
54	Connie:	There's no plus sign.
55	Andrew:	There is no box.
56	Brian:	Well, there's...
57	Andrew:	Those boxes are so small. I can barely see those boxes.
58	Connie:	No.
59	Brian:	Plus, and plus.
60	Andrew:	So-
61	Connie:	Right where? What? Oh, plus, plus.
62	Brian:	Okay.
63	Andrew:	Wait.
64	Brian:	There we go.

Table C
Example I-R-E Conversations to be discussed in Chapter V

Conversation 8		Flames
1	George:	What evidence of a chemical reaction do you see in this lab?
2	Henry:	Change of color.
3	George:	Change of color.
Conversation 9		Flames
4	Connie:	Do I see green? Ah.
5	Group:	Whoa.
6	Brian:	That's greenish-blue.

APPROVALS

IRB Approval

UNIVERSITY OF ARKANSAS

To:	Jennifer Oramous BELL 4188
From:	Douglas J Adams, Chair IRB Expedited Review
Date:	09/18/2020
Action:	**Expedited Approval**
Action Date:	09/11/2020
Protocol #:	1809145859R002
Study Title:	A Conversation Analysis of Student- to- Student Conversations in Modeling Classrooms
Expiration Date:	09/30/2021
Last Approval Date:	10/01/2020

The above-referenced protocol has been approved following expedited review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Bill McComas, Investigator